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THE PINTSCH SYSTEM OF GAS LIGHTING has now been introduced in the 6th avenue trains of the Manhattan Elevated R. R. in New York; 300 cars have been equipped with it. It is a complete success, and a vast improvement over the old system of lighting by oil lamps. It took some years of newspaper agitation, supplemented by an act of the legislature, however, to compel the company to make the change.

GAS AT $1 PER THOUSAND cubic feet has been furnished in Boston now for two years, since the General Assembly passed a law establishing its price, in obedience to public clamor, but the people are not satisfied with it. They now complain that the gas is poisonous, containing more than 30% of carbonic oxide. Forty deaths are said to have taken place from asphyxiation, and nearly as many more narrow escapes from fatal inhalation of the gas, from Feb. 5, 1896, to Jan. 4, 1897.

THE TENTH ANNIVERSARY of the use of natural gas in Indiana will be celebrated at Anderson, Ind., on April 7. Arrangements are being made by the Commercial Club for a demonstration and a banquet. A review will be given of the advancement and evolution in ten years from a country community, depending upon agriculture, to a community which is known in all parts of the world for its exports of manufactured wares.

SLOW SAND FILTRATION AT CUMBERLAND, MD., with aeration and sedimentation, has been recommended by the water commissioners of that place, in accordance with a report and estimates made by Churchill Hungerford, of New York city. It is proposed to build two 3,000,000-gallon settling basins and three filter beds, with a total area of one acre. A 4,000,000-gallon pump would lift water through a 14-in. main, 1,600 ft. long, to the settling basins, air being forced into the main with the water. The estimated cost of the whole plant is $30,559, including six acres of land. It is reported that the city council has postponed action on the report, and requested the water commissioners to investigate "the recently discovered system of water purification by electricity and ozone gas."

THE PROPERTY OF THE NEW ORLEANS SEWERage Co. was sold at auction on March 25 for $93,500. It was bought for the American Loan & Trust Co., of Boston. The company secured a franchise in 1892, but thus far has built only some five or six miles of sewers.

THE GREATER NEW YORK CHARTER BILL has passed the New York State Senate, by a vote of 39 to 9, and is now to be sent to the Mayors of the three cities interested, and submitted to public hearings.

PITTSBURG, PA., HAS A NEW CITY CHARTER under consideration. The Rodgers bill, which seems to be preferred, clothes the Mayor with full power to appoint heads of departments, now elected by councils, and places all responsibility for these appointments upon him. He may remove such officials, on stating his reasons to the Select Council, and may disapprove of items in any appropriation ordinance without disapproving the whole bill. The delinquent tax-collector is done away with by creating a department of receiver of taxes, and making the treasurer a disbursing officer and the custodian of funds collected. Another section provides that the Comptroller cannot countersign a warrant unless the money is actually in the treasury. A sinking fund commission would be created; the method of electing members of council changed, and hereafter, in all contracts for improvements to be paid by assessments, the contractor must look to these assessments for his claim, and the city will not be held responsible.

THE MOST SERIOUS RAILWAY ACCIDENT reported in the press despatches during the past week was one that took place on March 24 at Eagle Hill, O., on the Cleveland & Marietta R. R. A south bound local freight train ran into a landslide, and the engine and five cars plunged into the Tuscarawas river. The engineer received internal injuries and the fireman had his arm mangled.

THREE CAR AXLES HAVE BROKEN on the new motor cars of the Brooklyn Bridge within a fortnight. The axles were of steel and were made by the Cambria Iron Co. An investigation and inspection of all the axles on the motor cars is being made, and the result will probably be their replacement by heavier axles of the same make and style. It is evident that the strains on a motor axle are different in character and much more severe than those to which an ordinary car axle is subjected, and that an especially great torsional strain is likely to exist at the instant of starting. The motor axle therefore should be very much heavier than an ordinary car axle, but how much heavier can only be determined by experience such as the Brooklyn Bridge cars are now having. It is fortunate that the accidents thus far have not been attended by any loss of life.

THREE FLY-WHEEL OR PULLEY ACCIDENTS were reported last week. The most serious one was at the blooming mill No. 2 of Edgar Thomson Steel Works, of the Carnegie Steel Co., at Braddock, Pa., on Mar. 24. The engineer was killed, and an assistant severely injured. Press dispatches say that the governor broke and the engine "ran off." The engineer got on top of the engine to repair the break when the wheel burst. The flying debris did a large amount of damage. A fragment struck a 2-ft. steam pipe, breaking it, and caused the mill to be filled with steam. The electric light plant which supplied the whole works, the Carnegie library and the residences of President Schwab and Genl. Supt. Morrison, was demolished. The damage to the electric plant is estimated at $25,000, and to the whole works $75,000, and it is stated that the mill will have to be shut down six weeks for repairs.

A 5-FT. DRIVING PULLEY BURST in the Manville cotton mill, at Manville, R. I., on March 25, wrecking one end of the weave shop, causing a damage of $3,000 and shutting down the mill, in which 1,400 hands were employed.

THE FLY-WHEEL OF A MACHINE for grinding food for cattle burst near Denning, Md., on March 24, injuring four persons, one of them seriously.

A STEAM BOILER EXPLODED in the power-house of the electric street railway in Elmira, N. Y., on Mar. 29, killing the fireman and seriously injuring the engineer. The power-house and four cars were wrecked.

THE FLOODS ON THE MISSISSIPPI have reached a most dangerous stage. Several breaks in the levees have occurred, other breaks are feared and a vast extent of territory is now under water. Three breaks in the levee were reported on March 29, one at Lake Lee, ten miles below Greenville 1,500 ft. in width, the second at Perthshire, 48 miles north of Greenville, and the third a slight break at New Orleans. On March 30 further breaks were reported, one at Mound's Landing, 15 miles north of Greenville, and one at Australia, twelve miles north of Rosedale. It is believed that all of Bolivar, Issaqueau and Washington counties, and parts of Sunflower and Sharkey counties will be under water within a few days. A dispatch from Vicksburg states that the river is higher at that point than at any time before in 35 years. The government Weather Bureau reports that the river is above the danger line from Cairo to New Orleans, and from Memphis to Arkansas City it is above the extreme high-water mark of any previous year.

THE BREAKING OF A SEA-COCK VALVE caused the sinking of the ocean-going steam tug "L. F. Walcott," 20 miles southeast of Seabright, N. J., on March 27. The captain and crew were rescued by another tug. The accident was similar to that which recently caused the sinking of the U. S. battle-ship "Texas," in her berth at the Brooklyn Navy Yard. The sea-cock was on the 8-in. pipe which supplied the circulating pumps, and all attempts to stop the flow proved unavailing. The tug sank within 40 minutes of the time the valve broke.

THE SUSQUEHANNA RIVER is flooding a coal mine belonging to the Lehigh & Wilkesbarre Coal Co. at Avondale, Pa. Pumps have been erected, but little headway has been made in reducing the level of the water, and it is feared that the mine will be ruined.

THE RESUMPTION OF HYDRAULIC MINING in California, concerning which brief mention was made in our issue of Jan. 28, has been advanced a stage by the signing of the bill passed by the state legislature appropriating $300,000 for dredges and $250,000 for retaining dams. The San Francisco "Chronicle" of March 23 condemns the measures as special and private legislation, and says that great as are the sums appropriated for the benefit of the hydraulic miners they are destined to be nothing more than a beginning.

THE MASONRY WORK ON THE NEW DAM at Minneapolis is reported as having been completed on March 20. The dam has been built across the Mississippi River, not far below the old dam, by the St. Anthony Falls Power Co. Mr. Wm. de la Barre, M. Am. Soc. C. E., is engineer of the company.

A DAM ACROSS THE DELAWARE RIVER, at Trenton Falls, is authorized by a bill which has just passed the New Jersey legislature. Authority from the Pennsylvania legislature must also be secured.

THE MATHER NIAGARA RIVER POWER BILL is now before the New York Legislature. By this bill Mr. A. C. Mather, of Chicago, seeks authority to construct one span of a bridge across the Niagara River at Buffalo, intended ultimately to cross the river, and to attach to this experimental span a set of power-wheels to be driven by the current. One clause of the bill provides that 10% of the net profits of the enterprise is to be used in establishing and maintaining, in Buffalo, a school of applied electricity in the mechanic arts and in medicine; and any surplus funds are to be devoted to developing meritorious inventions made by students of this school. This fanciful feature of the bill is opposed, and a similar bill, without the school provision, was vetoed by Governor Morton in 1895.

THE CANADIAN NIAGARA POWER CO.'S REQUEST for an extension of time in which to complete its work has been favorably reported on to the legislature by the Queen Victoria Niagara Falls Park Commissioners. It is believed that the Government's action will be favorable to the company. The commissioners recommended an extension of 18 months, subject to certain conditions.

THE CONTRACT FOR 600 STEEL CARS of 100,000 lbs. capacity each, for the new Pittsburg Bessemer & Lake Erie R. R. has been awarded to the Schoen Pressed Steel Co., of Allegheny, Pa. The cars are to be double-hopper ore cars, 30 ft. long, over end sills, and the whole order is to be delivered by Aug. 1. The cars are to be equipped with Westinghouse friction buffers.

THE TONNAGE RATING SYSTEM for freight trains on the Baltimore & Ohio Southwestern Ry. is said to have resulted in a saving in the cost of transportation. According to a statement credited to the General Superintendent, Mr. Rawn, locomotives under this system are pulling from two to seven more loaded cars per train than before. A simple but comprehensive set of blanks has been furnished the yard masters, and in making up the trains each locomotive is given as nearly as possible the number of tons which it has been demonstrated by experience it is able to haul. The system has also resulted in fewer complaints of locomotives being stalled with their trains on grades.

THE PLANS FOR THE BROOKLYN BRIDGE TERminals to accommodate the trains of the Brooklyn elevated railways have been changed to meet the objection made in an editorial note in our issue of March 18. Separate platforms for passengers taking Brooklyn elevated trains at the New York terminal will be provided on each side of one of the tail switching tracks.

CIVIL SERVICE EXAMINATIONS of candidates for appointment in the Department of Public Works in New York city are announced to be held as follows: April 20, engineering inspector of grading and paving; April 23, instrument maker and assistant engineer. We noticed last week an examination on April 12 for topographical draftsman. Owing to the resignation of Mr. Stevenson Towle, consulting engineer in the department, the civil service commission has been asked to examine Mr. E. P. North, M. Am. Soc. C. E., Water Purveyor, for promotion to this place.

WOODEN WATER MAINS of the Wyckoff pattern, made by the Michigan Pipe Co. of Bay City, Mich, have been in use for many years in the village of North Tonawanda, N. Y. About 17 miles of these wooden mains have been in service here for the past 11 years. In a recent letter, Mr. S. C. Woodruff, Superintendent of the waterworks at this place, states that the cost of repairs on these mains during the past 11 months was $0.17. The village is now laying 14 miles of additional mains of Wyckoff pipe, from 4 ins. to 10 ins. in diameter.

THE RESTRICTION IN THE HEIGHT OF BUILDings to 90 ft. in Chicago, passed by the city council, has been vetoed by Mayor Swift. The present limit is 155 ft., and Mayor Swift is of the opinion that it ought to stand.

THE SUSPENSION BRIDGE OVER THE OHIO RIVER, AT ROCHESTER, PA.

By E. K. Morse, C. E.

In 1895, a charter was obtained for a toll bridge over the Ohio River, connecting the boroughs of Rochester and Monaca, Pa. The United States authorities require not less than 90 ft. clearance at this crossing of the Ohio River; and as the Beaver bridge of the Pittsburg & Lake Erie R. R. was only 3,000 ft. below the chartered location, no span less than 500 ft. could be considered. The river interests demanded a channel span of not less than 600 to 800 ft. The construction of the proposed structure having been placed in my hands, a cantilever bridge was first designed, and estimates were made which called for a bridge 2,200 ft. long with a 700-ft. channel span, calculated to accommodate foot, wagon and street car traffic, and costing $230,000. As this outlay was considerably more than the travel would justify, the enterprise was abandoned for a year. In the meantime, I made several sketches and designs for long span bridges of minimum cost that were proportioned to meet the demands of suburban travel, with the result that a suspension type of bridge was chosen.

FIG. 1.—GENERAL VIEW OF SUSPENSION BRIDGE OVER THE OHIO RIVER AT ROCHESTER, PA.
E. K. Morse, C.E., Chief Engineer.

For the past 20 years, I have been constantly engaged in the construction and erection of the substructure and superstructure of bridges, either as contractor, engineer of construction, or both, and there are two things I always insist upon: (1) To "pin up" a bridge so that it may be safe against accidents to the falseworks; and (2) to place the portals early in position and see that they are well bolted, to protect the bridge against wind; this the portals will do even without all the laterals in place. I do not know of a suspension bridge with a properly designed portal; they all have their expansion points for stiffening trusses at the towers and are continuous between them. I claim this is radically and practically wrong, and is a serious technical violation. I would not build a suspension bridge where money could be obtained for a fixed span, for suspension bridges for highway purposes are limber, shaky and unsatisfactory structures in the majority of cases. Personal observations from a practical point of view led me to believe, however, that much could be done in the design of suspension bridges to correct what is unsatisfactory in usual practice. In designing the Rochester bridge, I had entire freedom to do as I chose, except that I was limited to a certain sum of money. The conditions necessitated exceedingly careful and close figuring to keep inside of the fixed sum of $175,000, which sum had to cover rights of way, substructure and superstructure, new dwelling and toll house combined, engineering, and, in short, all expenses. I started out to design a suspension bridge that would be stiff under a moving load and to a certain degree rigid, but not rigid to the extent of acting independently of the cables. With this object in view, I decided to clamp the cables to the tops of the towers and to rivet the stiffening trusses and towers together at the top and bottom flanges, a radical violation of all theory and previous practice.

Last winter I made a very critical examination of the Point Bridge, at Pittsburg, which I heard Prof. Sternberg, at Carlsruhe, Germany, in 1882, pronounce to be the finest type of suspension bridge in the world, and found among other interesting conditions in that bridge that both nests of rollers on the towers were rusted fast to the bed-plates, and had, to all appearances, been in that condition for years. These rollers were 5 ins. in diameter, 4 ft. long, carefully housed, free from dirt, and had no doubt first flattened a little, then slid, and finally rusted fast. They are in the same condition to-day, and will probably always remain so. The towers of the Point Bridge are composed of four posts under each eye-bar cable, 90 ft. high, 5 ft. apart on top and 15 ft. at the bottom. The posts have large sections, and are stiff and well braced; yet the motion on these towers under stress of moving loads was marked, the sensation being that of one traveling around a small ellipse having its major axis parallel with the longitudinal axis of the bridge. I hunted all over those towers for loose rivets and was surprised to find none, and neither could I see any bad effects from so free a movement. This discovery had considerable effect upon my design for the bridge here described.

The Rochester bridge, as designed and now built, has a channel span of 800 ft. and two side spans of 400 ft. and 416 ft. respectively, supported by two cables, and a viaduct 570 ft. long, with panel lengths of 16 ft., all made of medium steel. The roadway is 22 ft. wide in the clear, with two street car tracks and one 6-ft. sidewalk, and provision is made for another footway. The floor system and stiffening trusses, which are 18 ft. deep out to out (except at the towers, where they are 28 ft.), are designed for a uniformly distributed moving load of 80 lbs. per sq. ft. on the roadway, and a concentrated load of two 15-ton street cars coupled together and running at full speed, passing two others moving in the opposite direction. The cables and towers are proportioned for a moving load of 1,760 lbs., together with the static loads, and supports were placed under the viaduct at intervals sufficient to preserve the same section in the trusses throughout.

Having determined on a radical departure from what was considered best practice, I first designed the towers so that they would yield to the horizontal tension of the cables and still be stiff and strong. They have been made of four posts under each cable, eight to a tower, braced with solid plate and angle brackets at every 20 ft., with sway rods connecting the sets of posts. Two 2-in. anchor bolts, 10 ft. long, were used during erection to support the towers against wind storms. The solid bracing has made the towers stiff and they will act under cable stress as one member. The greatest and worst concentrated loading this structure will probably receive is the uniform loading over the channel span alone. Assuming the shore cables to be removed and the tower fixed at the bottom flange of the truss, the horizontal pull on the top of the tower posts, figured as one member, would deflect them towards the channel at the top, 18 ins., causing a unit strain of 43,155 lbs. The average elastic limit of the steel in the towers was 42,000 lbs. Deducting from the above unit strain the resistance, or support of the top flange of the trusses, the resultant stress is reduced to a little less than 35,000 lbs. per sq. inch. But the shore cables are actually acting in sympathy with the trusses to overcome the movement of the top of the towers towards the channel. The towers, their bracing and the trusses are all riveted members and are so much stiffer than expected that I doubt if the top of the towers ever deflects 6 ins., in which case no injury would result to the towers even if they were acting independently of the trusses and cables. During erection there were times of considerable unequal loading, and in no case, under the most careful observation, was there any perceptible movement in the tops of the towers. Nor has the travel up to this time developed any sign of excess stress or any marked movement. In fact, the oscillations have been less distinct than was expected, while the advantages of a clamped cable during erection are numerous, and all in the line of economy and safety.

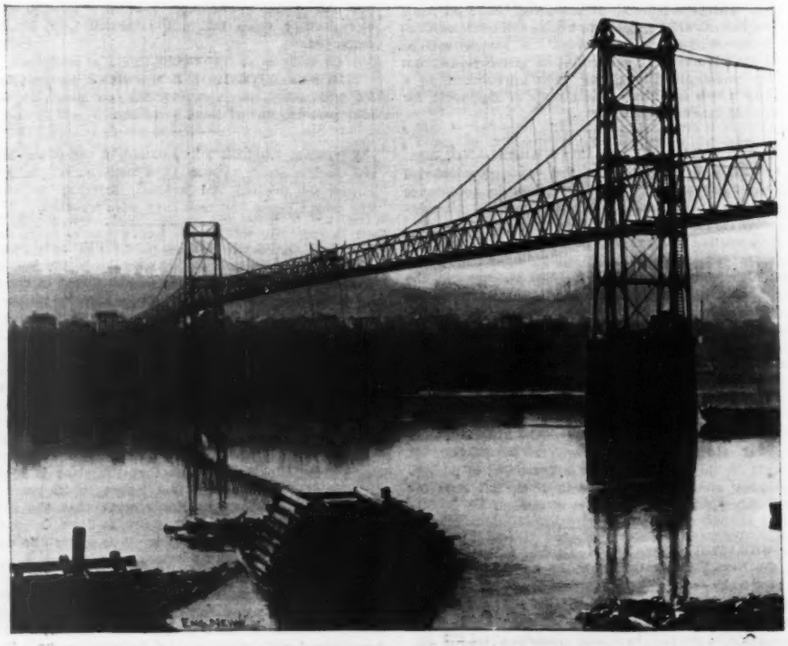

FIG. 2.—A NEAR VIEW OF THE ROCHESTER SUSPENSION BRIDGE.

This clamped cable once prevented a disastrous

accident. The foreman of erection had removed all but three bents of the trestle under the 400-ft. span, which was erected on trestles, and had about completed planking and the laying of rails, when, without the least warning, the trestle gave way. There was a rise of about 12 ft. in the Ohio River, and it is supposed that the trestle was weakened, though resting on piles. This took place when there was no flooring on the channel span and the trusses were not riveted up and only connected by a few bolts. The shore span sagged 3 ft. 7 ins. below the horizontal, throwing up the channel span and springing the tops of the towers 9 ins. out of plumb. The paint over the juncture of the tower clamp and cable was not even cracked. Figuring the oak lumber at 4 lbs. per ft., B. M., the timber load alone was 130 tons, and, coming as it did, with a jerk, the shock was severe and certainly more than can be again expected. The top flanges were buckled and twisted out of line, but apart from this, which was easily corrected, the closest and most thorough inspection revealed no injury. What would have been the result had the cables rested on nests of rollers on top of the towers? The bridge would have gone into the river; and of the 40 men at work upon it, many would have been killed. The propriety of flooring the shore span before placing a load on the channel span and riveting it up may properly be questioned; but the trestle was examined by the foreman and by myself several times and it seemed strong and at no time showed signs of weakness, as there were five piles under each bent and the trestle was well braced. The flooring was laid down to save time. Immediately after the accident the greater part of the flooring was removed, and the tower went back to its normal condition, the sag disappeared and the channel span settled down to its normal camber of 4 ft. The buckled pieces of the top chord were removed, and new ones were substituted, and but little time was lost. The accident solved a disputed point for once, if not for all time, and made plain the virtue of a clamped cable and tower. Many, if not all, suspension bridges have their expansion joints at the ends, just where the maximum wind pressure is exerted and must be transmitted to the towers. I have reversed this operation by throwing the expansion to the center of the channel span, where there is a close-fitting slip-joint, allowing for expansion and contraction, but no vertical or side motion. The expansion points in the flanking spans are at the ends, which have just enough bearing on their shoes to prevent too free motion. This disposition of the expansion points permits stiff bottom lateral bracing and destroys any motion or vibration in the trusses at the towers, which would pass from end to end of the span. Further than this, the trusses and cables are joined at each point of intersection by a strut crossing the roadway and riveted to each top chord and also firmly clamped to the cables. This arrangement added much to the stiffness of the trusses and practically destroyed the vibration and wave motion so common on light highway bridges.

In this bridge there are two piers in the river, extending just above high water and resting on piles. The anchorages are built of concrete, with stone facing above ground, resting on gravel bottom at a depth of 25 ft. below the surface of the ground. The stringers and beams are steel. The flanges of the stiffening truss are 12 × 14-in. T-shaped, with two 5×3½×5-16-in. angles forming the web members and riveted directly to the web of the flanges. The beam webs were punched out sufficiently to set over the web of the bottom flanges of the trusses and are riveted to each other by four angle bars; the bottom lateral angles are riveted to plates at each end and these are in turn riveted to the beam and flange, as well as to each stringer and at the center to each other, thus insuring perfect sympathy and maximum stiffness. As the construction of this portion of the work is a matter of common practice, I go direct to a description of the cables.

FIG. 3.—VIADUCT APPROACH TO ROCHESTER BRIDGE; WRAPPING MACHINES AT WORK ON CABLES.

There are seven strands to a cable; each strand is composed of 222 No. 8 B. W. G. galvanized wires averaging 200,000 lbs. breaking strain per sq. in. Each strand was made on the ground in a space arranged like a rope walk. The wire came in bundles of about 150 lbs., was brazed together and wound on reels holding ten bundles, from which it was strung out and woven backwards and forwards by hand over collars, at both ends, firmly bolted down to "dead-men." The strands were lashed about every 3 ft. for their whole length of 2,185 ft. Two strands were made at once, and on the average, in 10 hours, 22 trips would be made, laying 44 wires. Thus it took one day to clamp, lash and remove a strand. The length of the strands was obtained by stretching a wire from end to end of the channel span, passing over smooth running pulleys at the proper elevations at the top of the towers, and this length was found to be equal to the formula $L + 0.23\ h$; where L = horizontal length, and h = ver sine, or distance from highest to lowest center of cable. To guard against any possible error in taking this length, one end of the wire was fastened and the other adjusted until the channel elevation was obtained, and it was then carefully held at both ends until my inspector could climb to the top of one tower and I to the top of the other to test the movement over the pulleys. The pulleys were working smoothly, and I took the wire (No. 8 B. G.) between my thumb and finger, and ten times pulled it alternately forwards and backwards 2 ft., let it go, and each time, after playing to and fro like a pendulum, it came to rest at exactly the same pencil mark. Less pronounced movement, at the same time, took place over the pulley on the other tower and the wire came to rest at the same mark.

After the strands were made, they were placed in position by means of 1¼-in. steel carrying ropes, from which hangers attached to sheaves were lashed to the strands about every 50 ft., and these were strung out from the towers as the strand was pulled across the river, averaging one strand daily. After the seventh strand had been pinned, the channel strands were carefully adjusted and clamped to prevent their creeping. Each one was measured and marked to enable the foreman to adjust it as it was placed in position; he did this, but the change of temperature during the night caused the strands to creep several inches, and in every case, for some reason, from north to south. Immediately after adjustment the lashings from the strands were removed; the wires clamped and bunched into cables, and then the wrapping machines were started; the wrapping averaging about 30 ft. per day of 10 hours. This method of cable making is slow. The first strand was started June 26, and the wrapping on the first cable was started Oct. 28; yet only two weeks were consumed in erecting 1,200 ft. of the trusses and floor system after the cable was wrapped; the other 400 ft. of the trusses had been erected previously, as trestle-work had to be placed at one pier to provide length enough for the ropewalk for strand-making. The cables are wrapped with No. 10 B. W. G. annealed and galvanized wire. After wrapping, the cables were 7⅝ ins. in diameter; or after packing and wrapping as tight as possible, there were left in the cable just 37% of voids (loose sand has 33% voids). I might mention here that the cables are 20% stronger in proportion than the flanges and webs of the stiffening trusses.

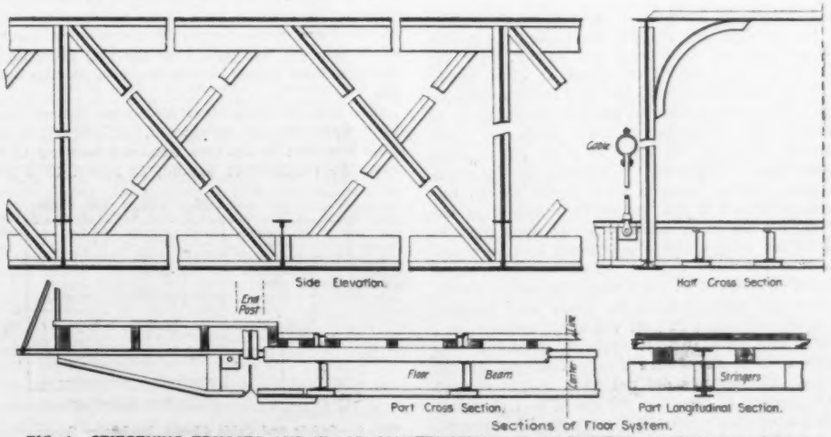

FIG. 4.—STIFFENING TRUSSES AND FLOOR CONSTRUCTION FOR ROCHESTER SUSPENSION BRIDGE.

There were many interesting details of construction and erection, but they are not appropriate for discussion here. My aim has been during this construction to practically meet the problems presented, and then to apply the best and most acceptable theory possible. The sympathetic action of the trusses, cables and towers

during the limited time of service to which they have been submitted is most gratifying, and I feel entirely satisfied that the departure from common practice here detailed has been a move in the right direction.

I have just completed plans for another suspension bridge on much the same lines of construction, but have adopted a cable made of wire ropes

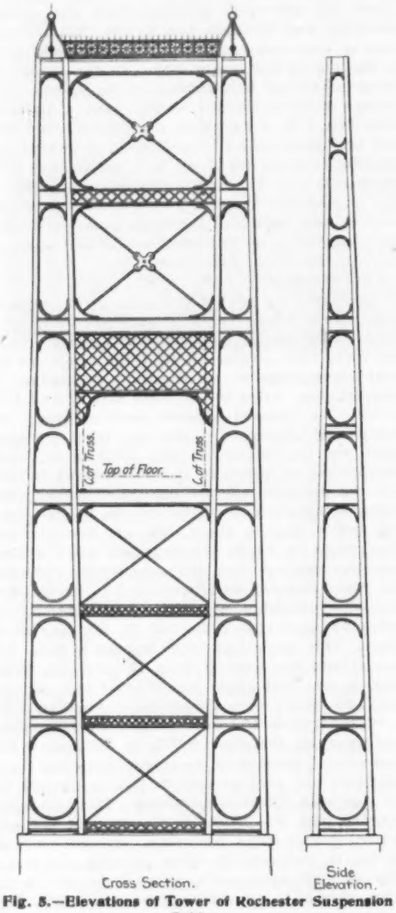

Fig. 5.—Elevations of Tower of Rochester Suspension Bridge.

for the strands, instead of strands made of wire on the ground. My reasons for so doing are that this method will save time and money, with results fully as good. The cables at close range will not be as handsome, but at 1,000 ft. distance they would look alike. In placing the strands in position the lashings become more or less bunched, allowing the wires to bulge out at some places; and in adjusting the strands for the channel span several strands were pulled at the anchorages 5 and 6 ins. before they moved at the center; on the other hand, other strands were so free of the bulges above mentioned and so sensitive that the least pull at the anchorages caused decided movement at the center. In other words, though the strands were all made and handled alike, no two acted in just the same manner, and careful and constant attention in grouping was required until they were finally clamped at the towers. The strands did not have weight enough in themselves to take out the slack, and they had to be pulled taut before they were finally clamped, after which no further trouble was experienced. A specially-made wire rope could be shipped complete from the factory, could be erected at once, and would stay where it was placed. For convenience in erection the ropes should be continuous from anchor to anchor. It would be next to impossible to erect them in lengths extending from tower to tower, and anchor to tower, especially between the latter points, if the cable were straight and supported no hanger loads. I doubt if the stretch (or lost deflection) of the wire ropes will equal that of the wire strands. A foot in height was allowed for this stretch in the Rochester bridge and it was not enough. The importance of this is better understood when we realize that the towers are 80 ft. high, giving a versed sine of 72 ft. on 800-ft. span, and that the line of curvature is only 816½ ft. long, or 16½ ft. more than the horizontal length for a rise of 72 ft., or nearly 5 to 1.

I am much indebted to the following persons for their faithful and intelligent inspection and for the carrying out of my specifications: John D. Anderson, inspector of masonry; A. B. Hine, C. E., graduate of Rensalaer Polytechnic Institute, and R. Albree, C. E., graduate of Sheffield Scientific School, inspectors of the superstructure, and to W. A. Aiken, who had charge of the wire inspection at Trenton. I am also indebted to David Ramsey, the foreman of construction for the Penn Bridge Co., who had the contract for the superstructure. The Jutte & Foley Co., of Pittsburg, were contractors for the substructure.

SOME EXAMPLES OF RECENT PRACTICE IN TURNTABLE DESIGN.

(With two-page engraving.)

In Engineering News of Sept. 10, 1896, attention was directed to the careful consideration which engineers were giving to the design and construction of turntables for the heavy locomotives of the present day, and a promise was made to present practical and useful examples of the most recent structures of this class at some future time. This promise is partly fulfilled by the drawings which are presented on the inset sheet accompanying this issue, and will be more fully carried out by future articles to be published as time and space become available. Before proceeding to the study of the particular designs illustrated at this time, however, it is desirable, even at the risk of a little repetition to examine briefly and in a very general way some of the theoretical and practical considerations which enter into turntable design and construction.

Theoretically a center-bearing single beam construction is the preferable construction for turntables. By this it is meant that the center-bearing carries the entire weight of the table and its load, leaving the end bearings free from load, and that the table acts as a single beam to resist strains. It is obvious that if such a construction can be made theoretically perfect, all the frictional resistance to turning is brought at the point where the greatest leverage is available to overcome it, and that diagonal deflection, with all its concomitant troubles is most nearly avoided. Only a more or less close approach to perfect construction is possible even if we consider the table by itself and neglect entirely the effect of loading it. It is plain, however, that the real disturbance of theoretical requirements comes with the loading.

This will be more clear if the process of turn table operation is considered. In operation the table has first to tip to a firm end bearing to receive the locomotive; second, to revert to a horizontal position with both ends clear, when the locomotive is fully balanced, and remain so while turning is in progress; third, to tip to a bearing at the opposite end when the locomotive leaves the table, and, fourth, to revert to its original horizontal position. This cycle of operations, even under the most uniform conditions of loading, introduces very evident variations in the character and intensity of the strains to which the table and its bearings are subjected, and the complications are increased by the shocks, thrusts and irregular distribution of a heavy dynamic load. With this explanation of conditions we are in position to understand the requirements which theory and experience have established for turntable design and construction.

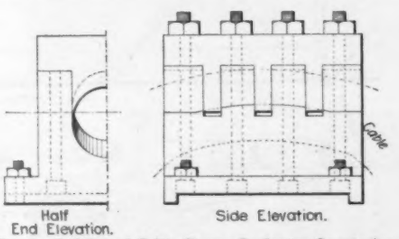

Fig. 6.—Saddle and Cable Clamp, Rochester Suspension Bridge.

These are, briefly, the following: (1) Necessarily the table must be long enough to receive and balance the largest locomotive and tender in use; (2) it should turn easily under all conditions of weather, i. e., snow and ice, and freezing or thawing should not disturb its adjustment or make it turn hard; (3) its wearing bearings need to be of such material and construction as to withstand the load, and not to be disturbed or thrown out of position by shocks or the end thrusts of locomotives entering and leaving the table; (4) it should swing true to center and preserve its adjustment horizontally and vertically; (5) it should be sufficiently rigid to swing under the heaviest loads with the outer ends of the table clear, or practically free from load, and yet be so flexible that the shock of the locomotive will not dangerously strain or perhaps break it; (6) all these features must be obtained with a minimum of first cost and cost in repairs and operation. There are of course many minor details to be considered, and some of these will be made clear by a study of the examples of actual structures which are presented in the accompanying drawings.

In studying these structures a few words of explanation are perhaps necessary. In all cases the illustrations are from drawings of structures actually built, which have been furnished us by the Chief Engineers of the various railways represented. In all cases also the illustrations show either the standard practice or else the latest improved designs from which turntables have been constructed. Wherever the construction could be made clear by description alone, illustrations have not been used, and on the other hand, where illustrations have been used the descriptive text has been abbreviated as much as possible. In general the construction of the center and end bearings has been illustrated, while the girder and bracing systems are described without illustration. The intention has not been to enter into minute details in respect to workmanship or material, since most of the centers illustrated are either of patented or special design peculiar to some one manufacturer, and details are always available by corresponding with the makers, but to illustrate and describe the characteristic features in such a manner as to afford a basis for prosecuting further investigations.

Cofrode & Saylor.

According to the catalogue of this firm, issued in 1891, some 60 railways used the turntable made by it, and since that time the number has been largely increased. The standard tables of the manufacturers will, therefore, be described here, and not the tables built for any particular railway. These are of two styles, viz., deck and half-through tables. In both styles the girders are riveted plate girders, with angle iron lateral and diagonal bracing, and are usually placed 5 ft. apart c. to c. The cross girders are made of plates and angles and are riveted to the main girders. The track system consists of wood cross ties, laid directly on the cover plates in the deck tables, and on angles riveted to the main girders in the half-through tables, and carry the rails in the usual manner. Figs. 1 and 2 show the methods of supporting the table on the center pivot, but the form of this pivot has been lately changed to the construction shown by Fig. 3.

Center Bearing.—The center pivot consists of the standard A, fastened to the masonry, the roller system B, the cap C and the saddle D carrying the table. The rollers are of forged steel, and the standard and cap are of cast steel. Dimensions and structural details are shown by the drawings. All parts of the pivot are made to exact gage, and are of the same size for all tables.

End Bearings.—The ends of the table are provided with two rollers each, traveling on a circular track in the usual manner, and also with latches. For adjusting the heights of the end wheels, packing plates are inserted between the journal boxes and the bottom of the channels carrying them. To adjust the height of the center bearing a packing plate is inserted between the

bottom of the standard and the top of the capstone to which it is bolted.

Pits and Foundations.—The character of the foundation varies of course on different railways, but they are usually of masonry, with the circular track rail resting on timbers laid on masonry. The tables are made for any dimension of pit up to 75 ft. diameter, and of special sizes above this diameter if desired. All parts are designed for consolidation locomotives of 86 tons weight, or equivalent loads.

Lake Shore & Michigan Southern Ry. Co.

All the turntables purchased by this company during the last five or six years have been riveted plate girder, deck structures of the pattern illustrated. Mr. E. A. Handy, M. Am. Soc. C. E., Chief Engineer, states that these tables have given uniformly good service. For illustration a 62-ft. table built by the Kings Bridge Co., of Cleveland, O., has been selected.

Table.—The main girders are riveted plate girders 62 ft. long over all, 4 ft. 6½ ins. deep at the center, 2 ft. 2 ins. deep at the ends, and spaced 4 ft. 7⅛ ins. apart c. to c. The top chord is horizontal and is made up of two 6×4×½ ins. angles, three 13×⅜ ins. cover plates, 61 ft. 11½ ins. long, 36 ft. 10½ ins. long and 10 ft. 6½ ins. long, respectively. The bottom chord is horizontal for a distance of 16 ft. 6 ins. at the center and then bends up toward the ends. Its composition is similar to that of the top chord. The web is ⅜-in. thick and is stiffened by twelve 3×3×⅜ ins. double angle stiffeners.

The main girders are braced together by center and end cross girders, four vertical sway bracing systems and top and bottom lateral systems. The sway bracing and lateral systems are made up of 3×3×⅜ ins. angles.

Center Bearing.—The table is supported on the center pivot by means of center cross girders of the form and construction shown by Fig. 1. Fig. 2 shows the construction of the center pivot, in which A is the cast steel standard, B a ring of 13 cast steel rollers, C and D cast iron and cast steel rings holding the rollers in position, E the cast wheel cap, F the cast iron saddle carrying the table, and G a wrought iron dowel to hold the saddle from slipping off the cylindrical cap bearing. It will be noticed that the axis of the cylindrical bearing face on top of the cap E runs transversely to the longitudinal axis of the table and allows it to tip longitudinally, but not transversely.

End Bearings.—Full details of the end girder and bearing construction are shown by Fig. 3, and they need not be described further, except to state that the end wheels are of cast iron 13 ins. in diameter.

Lehigh Valley R. R. Co.

The most recent turntables built by this company are plate girder, deck structures, 64 ft. long, calculated for an equivalent load of 4,000 lbs. per lin. ft. For illustration a 59 ft. 6½ ins. table has been selected. This table was built by the Union Bridge Co., of New York, N. Y., and has the center and end bearings most commonly used by the railway, although other center and end constructions are also used. The matter for the accompanying illustrations has been furnished by Mr. Charles E. Webster, Chief Engineer, Lehigh Valley R. R.

Table—The main girders are riveted plate girders 59 ft. 6½ ins. long over all, spaced 5 ft. apart c. to c., and constructed of soft steel. The top chord is horizontal and consists of two 6×4×9-16 ins. angles and three cover plates 14×½ ins.×50 ft. 7 ins., 14×½ ins.×43 ft. 11 ins., and 14×7-16 ins. ×23 ft. 3 ins., respectively. The bottom chord slopes up from the center line in each direction toward the ends, and its composition is practically the same as that of the top chord, except for the slightly greater length of the members necessitated by the rise from the horizontal. At the center the girder is 4 ft. 6 ins. deep back to back of angles, and at the ends the corresponding dimensions are 2 ft.4 ins. The web is ⅜-in. thick and is stiffened by 3×3×5-16 ins. angles, with the usual filler and splice plates. The girders are braced together by two plate cross girders, which connect with the center bearing, two end girders, two intermediate cross frames of 3×3×5-16 ins. angles and a top and bottom triangular lateral systems also of 3×3×5-16 ins. angles, all disposed symmetrically with respect to the center. The track system consists of cross ties laid directly on the cover plates and carrying the rails in the usual manner.

Center Bearing.—Fig. 1 shows the construction of the center bearing, which consists of the cast iron standard A, the cast steel yoke bearing B, the bronze disk C, the steel suspenders D, and the side bearing wheels E. Fig. 2 shows the center bearing girders in detail and taken in connection with Fig. 1 explains clearly the whole center bearing construction.

End Bearing.—Each end of the table is carried on two 15-in. wheels supported by journals carried by two transverse end frames of the design shown by Fig. 3. These wheels travel on a circular track of 28 ft. 13-16 in. radius.

Pit and Foundations.—The turntable pit is 60 ft. in diameter and is surrounded by a masonry wall with an offset which carries the track rail directly upon the masonry. The center pier is also of masonry, with a square capstone to which the cast iron center pivot is bolted. The bottom of the pit slopes radially from the circumference and also from the center to an annular depression, or sump. Mr. Charles E. Webster states that this turntable construction has given the company excellent service.

Louisville & Nashville R. R. Co.

The turntables purchased by this company during the last few years all have either Piper or Greenleaf centers. Mr. R. Montfort, M. Am. Soc. C. E., Chief Engineer, writes that the practice of the road usually is to secure bids from a number of contractors under specifications which prescribe that the table shall be built for a 150-ton consolidation engine, and that the stress in top and bottom flanges shall not exceed 10,000 lbs. per sq. in.; also that the webs shall not be less than ⅜-in. thick and shall be thoroughly stiffened and braced. The Piper center will be illustrated in connection with the standard construction of the Pennsylvania R. R. Co. in the concluding article on this subject, and the Greenleaf center was illustrated in our issue of Sept. 10, 1896.

Louisville, New Albany & Chicago Ry. Co.

Regarding the latest practice in turntable construction by this company, Mr. Ferd. Hall, M. Am. Soc. C. E., Chief Engineer, writes as follows:

We have no standard plan of turntable. We have all styles, including over trussed wooden tables, cast iron tables, and steel girder tables. Our last table built I consider equal to future requirements. This is 70 ft. long, 125 tons capacity, based on a unit, strain equal to twice that in bridge construction. One thing above all others we have found, and that is that the center bearing made by the Greenleaf Turntable Co. is the best and most satisfactory. This table that I mention has no end wheels, but the entire bearing is on the center, the ends being perfectly free. My opinion is that end wheels should be used not to bear when a maximum load is on the table, but more for the purpose of keeping the table within certain limits when the engine may for some cause be loaded heavily on one side. There is one element in favor of a table with no end wheels and that is the convenient form of latching, which is simply to permit the end girders to drop into a cast iron recess when a load comes upon the table. It is thus held perfectly and never misses latching. To give the life of a table from what we have discovered in actual experience would be in a large measure guess work. The tables constructed on this road previous to 1885 were less than 60 ft. in length and generally not over 60 tons capacity. This actual load has been exceeded and we have been obliged to replace tables, in one place taking out the table of 60 tons capacity, riveted girder construction, and putting in with the same center cast iron arms, estimated at 100 tons capacity. On taking out the riveted table we found that the web had corroded nearly half its original thickness. With ordinary steel I believe that turntables should be constructed having no unit tensile strain per square inch of over 15,000 lbs.; should be built for at least 125 tons capacity on this basis, and should be 70 ft. long, or at least long enough to turn the longest passenger, sleeping or private car.

The Greenleaf table mentioned by Mr. Hall was illustrated in detail in Engineering News of Sept. 10, 1896.

Minneapolis, St. Paul & Sault Ste. Marie Ry. Co.

The standard turntable used by this company is a 60 ft., plate girder, deck structure designed for a consolidation engine and tender weighing 210,850 lbs., and built after the designs of the Detroit Bridge & Iron Works, Detroit, Mich. We are indebted to Mr. W. W. Rich, M. Am. Soc. C. E., Chief Engineer, Minneapolis, St. Paul & Sault Ste. Marie Ry., for the matter from which the accompanying drawings have been made.

Table.—The main girders are 60 ft. long, 4 ft. 6 ins. deep at the center, 2 ft. deep at the ends, and spaced 5 ft. apart c. to c. The top chord is horizontal and the bottom chord curved, with a radius of 181 ft. 3 ins. Each chord is composed of two 6×6 ins. angles and two cover plates, one 13×⅝ ins. ×23 ft. 10 ins., and the other 13×⅜ ins. ×11 ft. 6 ins. The web is ⅜-in. thick and is stiffened by 3×3 ins. angle and filler stiffeners. The girders are braced together by two plate cross girders at the center, two end girders, four vertical sway bracing systems, and a triangular lateral system in the plane of the top chord. The sway bracing and lateral systems are made up of 3×3 ins. angles. All rivets are ¾-in. and all riveted work soft steel. The track system consists of cross ties, laid directly on the top chord and carrying the rails just inside of the centers of the girders.

Center and End Bearings.—The construction of the center bearing is shown by Fig. 1 in such detail that little description is necessary. The end bearings are roller bearings, and their construction is shown by Fig. 2. Attention is directed to the end latches.

Pit and Foundations.—The diameter of the pit is 60 ft. 6 ins., and its bottom slopes radially toward the center. The side walls are of masonry, but the circular track rests on the ground. It will be seen that the cast center bearing rests on a circular capstone carried on a masonry foundation. The diameter of the circular track is 58 ft. 5 ins.

New York Central & Hudson River R. R. Co.

The turntable illustrated here is rather a special than a standard construction, it having been designed by Mr. Walter Katte, M. Am. Soc. C. E., Chief Engineer, for the 72d St. engine house of this company in New York city, where the limited depth available for foundations precluded the use of a deck table. In sending us these drawings Mr. Katte wrote as follows:

This is rather a special design than a standard type. It is, as you will observe, of the through type instead of the ordinary deck form. Being unable to obtain the necessary depth for foundation for this particular location we found it impossible to use the ordinary deck form. Of course, wherever the proper depth can be secured the best results are obtained from the deck type, so as to permit the introduction of rigid cross bracing to resist the twisting tendency which always results from uneven loading of the engine and tender.

This design being the only one presented for a through table and also being somewhat unusual, it has been thought desirable to illustrate it in some detail in Figs. 1 to 3. Fig. 1 shows various sectional views and a part plan and elevation explaining the girder, sway bracing and floor construction. It will be noticed that the table is carried on a drum revolving on a train of rollers exactly like a swing bridge, and also has a bearing on a center pivot by means of adjusting frames.

The center pivot, drum and roller construction are shown by Fig. 2, in which A is the steel center casting bolted to the masonry and carrying the loose rings B and C, to which the inner ends of the spider rods D and the radial drum struts E are bolted. There are 14 spider rods, each carrying a cast iron wheel F. The wheels of this ring are held in position peripherally by 3×½ ins. steel bars connecting at G and H. There are six radial drum struts. On top of the center casting A is the cap J carrying the gun metal bevel ring K. A similar bevel ring encircles the cylindrical pivot of the saddle L, which is rectangular in top plan. Between the bevel rings is a train of 25 steel rollers, M. The bearing on the saddle M is obtained by means of the construction shown in detail in Fig. 3 and in position in Fig. 4. It will be seen that the two yokes carrying the adjusting rods rest on the planed faces X and Y of the saddle L, with their longitudinal axes parallel with the center line of the table. Fig. 4 shows how adjustment is secured by this yoke and also shows the manner of supporting the table on the drum. Other details are clearly shown by the drawings. Fig. 1 shows the construction of the end bracing and Fig. 5 details of the trailing wheel construction. All other essential details of the table and its bearings will be understood by a study of the drawings. The material is steel except where otherwise noted. The table is being built by the Elmira Bridge Co., of Elmira, N. Y.

(To be continued.)

VOLTAGE REGULATOR FOR DIRECT AND ALTERNATING CURRENTS.

We illustrate herewith an instrument known as the Chapman direct and alternating current voltage regulator. It is manufactured by the Belknap Motor Co., Portland, Me. It is used chiefly for preserving a uniform voltage in current generated for incandescent electric lighting purposes, by varying the field strength in the dynamo as the speed of the armature shaft changes

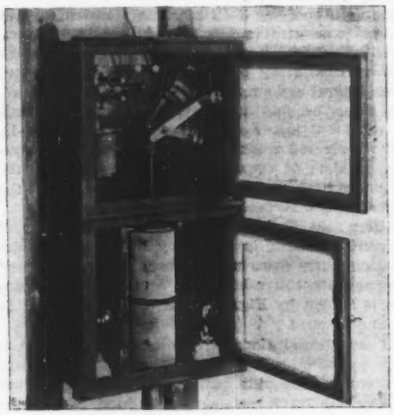

Fig. 1.—The Chapman Voltage Regulator. Manufactured by The Belknap Motor Co., Portland, Me.

The device is essentially a field rheostat whose operation is automatic. The moving of the rheostat arm is accomplished by the action of a working solenoid, the actions of which are determined by those of an auxiliary solenoid which operates a set of contacts that control the admission of current to the sections of the working solenoid. The working solenoid is differentially wound and is composed of four distinct coils, two of which have a small continuous current flowing through them, in mechanical opposition to each other; the contacts close the circuit of one or the other of the remaining coils and so neutralize the action of one of the continuously acting coils.

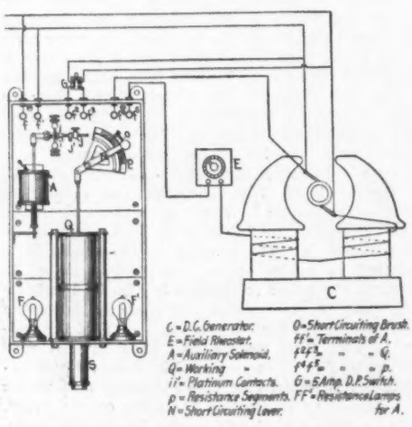
C = D.C. Generator.
E = Field Rheostat.
A = Auxiliary Solenoid.
Q = Working "
I I = Platinum Contacts.
p = Resistance Segments.
N = Short Circuiting Lever.
O = Short Circuiting Brush.
f f' = Terminals of A.
f g' = " " Q.
f' g' = " " p.
G = 5 Amp. D.P. Switch.
F F' = Resistance Lamps for A.

Fig. 2.—Diagram Illustrating Operation of the Chapman Voltage Regulator when connected to a Dynamo.

This manner of connecting secures a rise of magnetism in the iron core of the solenoid whenever a break occurs at the contacts and so avoids any injurious sparking at the contacts that would naturally occur by the magnetic discharge of the core. The arrangement completely neutralizes the induction discharge and no induction spark can occur. All of the usual objection to contact points is thus entirely removed, and they may be set very close and thereby secure the most sensitive adjustment of the apparatus.

The entire work of the auxiliary solenoid is to move a lever arm with contact attached through a short space of say 1-32-in., and a very slight change of voltage is sufficient to do this. It is often desirable to have the voltage at the generating station rise a little with the load so that it becomes greater than the voltage at the distributing center where it remains constant with changes of load. This result is aimed at in the compound winding of the generators, but, in most cases, is far from securing the result desired on account of the changes of speed, which no compounding of the generator can compensate for. The compounding of the auxiliary solenoid, however, secures the desired result under all conditions of speed or load, and a plain shunt wound generator becomes just as effective as a compound wound generator. The use of the regulator enables the old style direct or alternating current generators having no compound coils to do as good work as the more modern apparatus.

The energy consumed in the regulator is so small as to be negligible. The large working solenoid requires the use of only 60 or 70 watts of energy, and the rheostatic part of the device is concerned only with the current in the shunt winding of the generator, which is a very small percentage of the output of the machine. The regulator may be operated on a machine of 150 K-W., with an extra expenditure of energy not exceeding ¼ HP. By the use of the regulator it is claimed that mills and factories can run light plants from their main shafting without the necessity of special engines, even if there is a variation of 50% in the speed above the normal.

THE BROOKLYN ELEVATED RAILROAD CO. went into the hands of a receiver on March 25. The proposed reorganization includes an assessment of the stockholders and the scaling down of the interest on the outstanding bonds from 6% to 4%, the inducement to the bondholders to accept this scaling being an issue to them of new common stock, which at present will have only a nominal value. The agreement provides for an issue of $13,000,000 of common and $5,000,000 preferred stock, and $16,000,000 new 4% bonds. Of the latter about $11,800,000 will be required to retire the old bonds, and the proceeds of the remainder are to be used to complete extensions of the roads, to change the cars and the motive power in case the company is permitted to operate its cars over the Brooklyn Bridge, and eventually to change the motive power of the system from steam to electricity. It is stated that more than 80% of the security holders have already agreed to the proposed plan of reorganization.

SUSPENSION BRIDGE OVER THE OHIO RIVER AT EAST LIVERPOOL, O.

By Hermann Laub, C. E.

The Ohio River bridge at East Liverpool, Ohio, is of the stiffened suspension type, designed for highway and electric railway traffic. The approach on the Ohio side consists of 140 ft. of steel trestle work, and extends to the Ohio anchorage, where the bridge proper begins. The main bridge consists of three spans; the Ohio, 360 ft. long, the Channel span, 705 ft. and the West Virginia span of 420 ft.

Both anchorages are of second-class masonry, built of Beaver Valley and Ohio sand-stones, laid in Louisville cement. The anchor-chains themselves are thoroughly imbedded in cement-mortar. The foundation material for these anchorages was sand and gravel, and the space between the walls is filled with gravel. The anchor-girders extend over the whole width of the anchorage, and are also bedded in concrete.

The masonry piers, which are 60×22 ft. at the bottom and 13×43 ft. on top, extend 5 ft. above high water, and are built of first-class masonry, with concrete backing. They were sunk in 15 ft. of water with open caissons, on solid grillage platforms, 4 ft. thick, after dredging was completed down to hard gravel bottom.

To secure sufficient stability in the iron towers, which rest on iron beams and plates, laid in Portland cement on the piers, iron girders have been placed in the masonry 16 ft. down from the top of the piers, and these are connected by heavy iron rods to the bases of the posts of the towers. These towers are built each of four heavy columns, braced as shown on the plans. They are 106 ft. high from top of masonry to top of cables, or 160 ft. from top of cables to low water line.

The cables rest on cast iron saddles 6 ft. long, and these again on a set of 15 6-in. interlocking rollers on top of the tower posts. The cables are built of seven strands of 200 No. 8 B. W. G., oiled steel wires, made by John A. Roebling's Sons, of Trenton, N. J. The ultimate strength of these wires is from 190,000 to 205,000 lbs. per sq. in. The elastic limit is from 95,000 to 100,000 lbs. per sq. in. The length of the cables is about 1,515.5 ft.; and the lengths of the strands varied somewhat on account of their different positions in the cables, and around the saddles, as also on account of their connections with the anchor-posts of the anchorages. These variations were carefully computed and allowance was made, when the strands were built.

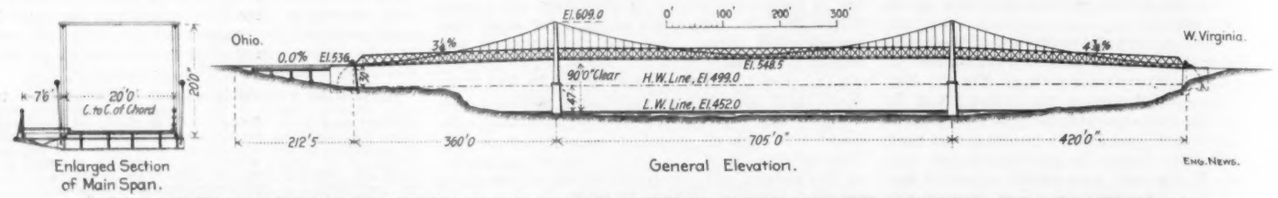

FIG. 1.—GENERAL ELEVATION AND SECTION OF MAIN SPAN OF SUSPENSION BRIDGE OVER THE OHIO RIVER AT EAST LIVERPOOL, O.
Herman Laub, C.E., Chief Engineer.

The cable strands were built near the West Virginia end of the bridge, two at a time, the ends being fastened while built to substantial dead-men, placed 1,515 ft. apart. The coils of wire, as received, were wound on upright reels, the end of each coil being brazed to the next. Two links were then fastened to the dead-men as far apart, center to center, as the strand was long. One end of the wire being made fast, the wire was passed round the links until one hundred complete turns had been made. The wire was then cut from the reel and the two ends in the strand brazed, thus making the strand an endless wire. The strand was then well oiled with linseed oil and tied every 14 ins. with a few turns of No. 14 B. W. G. soft

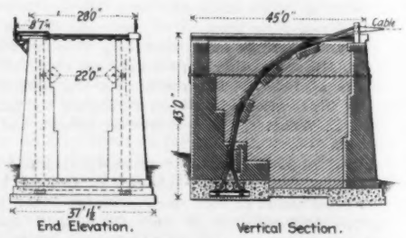

Fig. 2.—Sections of Anchorage, East Liverpool Suspension Bridge.

iron wire, the strand being clamped with stout tongs before tying. The strand was then laid aside and another or- started.

The strand was supported while under construction by short posts, placed at intervals of 50 ft., each post carrying a U-shaped casting which held the wires together. At one of the dead-men these posts were omitted for a space of 225 ft., and the wires allowed to sag 36 ins. By making this sag the same for each wire, the tension of the wires in the strands was kept uniform. As each half turn was made round the links, the proper sag was secured by drawing or slacking the last wire at the dead-men. A carefully measured guide wire was used to lay off the lengths of the strands, it being clamped at the links and having the same sag as the strand. Arrangements were made at one of the dead-men for varying the length of the strand as the temperature changed, thus keeping the sag as nearly constant as possible. The links in the ends of the strands are cast steel, ¾-in. thick, slotted so as to permit 6 ins. adjustment, and the least radius of the ends of the links is 4¼ ins. Thirty-three days of 12 hours each were required to complete the 14 strands.

While the strands were being built wooden frames were erected on top of the towers. The top timber of the frame was 8×16 ins. yellow pine and projected over the saddles about 5 ft. above them, forming a support for the trolley pulley wheels. Two 1⅛-in. wire trolley ropes were run across the river over these pulleys and the ends fastened to dead-men back of the anchorages. Means were provided for varying their lengths as the occasion required.

To raise a strand it was placed on rollers and a 1½-in. manila line leading over the towers to an engine across the river, was attached to it. It was then drawn across, being suspended every 50 ft. to a grooved wheel running on the trolley rope. When across, the pins were driven in the links, the trolley wheels removed and the strand lowered into the saddle with a steamboat ratchet.

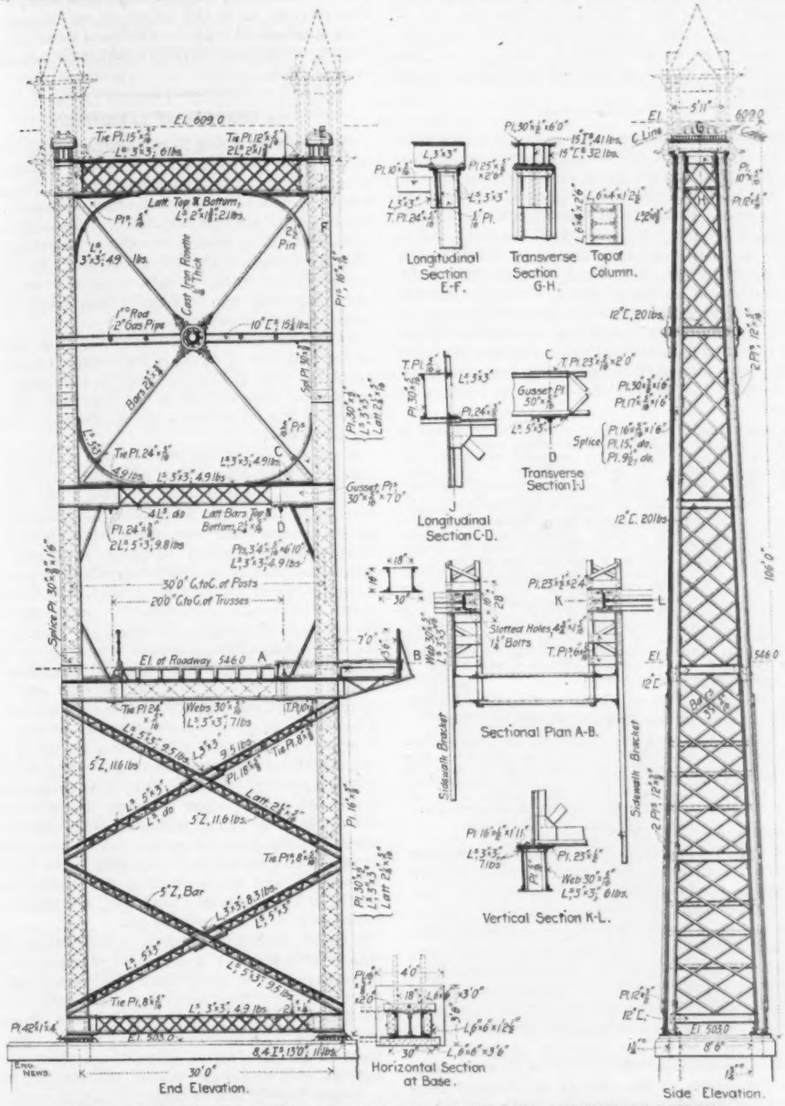

FIG. 3.—TOWERS AND TOWER DETAILS; EAST LIVERPOOL SUSPENSION BRIDGE.

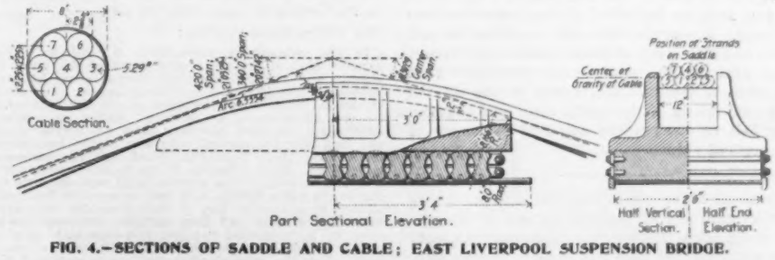

FIG. 4.—SECTIONS OF SADDLE AND CABLE; EAST LIVERPOOL SUSPENSION BRIDGE.

The first strand of each cable was marked to show where it came on the saddles and the others were given the proper deflections in the center span to agree with the first. After the cables were all up, the end span strands were adjusted by drawing the links back and pouring babbit metal between them and the pins when the right position was secured. About 8 hours were required to raise one strand. After the strands were adjusted the tie wires were picked out and the cables were clamped at intervals of about 15 ft., beginning at the centers and working toward the shores. Wrapping machines were then placed on the cables, starting at the centers and working towards the towers. The wrapping wire was No. 10 B. W. G. soft steel wire, the ends of the bundles being brazed to make the wrapping continuous. The machines averaged about 3 ft. an hour, and the men working on the cables were carried on platforms suspended by falls from pulleys running on the wire trolley ropes. The cages, as they were called, were moved by lines running ashore to the engines, speaking trumpets being used to signal the engineer.

The wrapping is secured where it ends at the towers and anchorages by clamps of 4×¾-in. iron. A 4×⅝-in. clamp is also placed on each strand about 3 ft. from the end. The diameter of the finished cable, including wrapping, is 7.33 ins., while the diameter of the single strands is about 2⅞ ins.

The hangers were placed on the cable as soon as the wrapping was done. The clamps are steel castings 6 ins. wide × ¾-in. thick, made in two pieces and bolted together by a ⅞-in. bolt. The stiffening trusses for all these spans are 20 ft. high and 20 ft. wide throughout, and are suspended from the cables with iron hanger rods and floor beams every 15 ft. They are disconnected at the towers, where provision is made for the expansion of the trusses. At the centre of the centre span four panel points are rigidly connected with the cables in order to divide the expansion equally on both towers for the middle span. The ends of all three trusses are solidly anchored so as to prevent any upward or downward movement, produced by movable loads or changes of temperature. The chords are made of plates and angles of a T-shape, and the web system of angles of the double triangular type, and all joints are riveted together. The bottom wind braces are also stiff members while the top lateral system is made of beam struts and adjustable rods. The stresses for these trusses have been carefully calculated for partial loads, changes of temperature, and wind loads, and the members are proportioned accordingly. On account of the small deflection of the cables at the end spans, the trusses for these spans had to be made very heavy as compared with those of the centre span, with the purpose of obtaining the same stiffness against vertical moving loads for the whole bridge.

This bridge was opened for traffic on Jan. 1, 1897. Work was commenced upon it on March 10, 1896. The bridge is remarkably stiff under moving loads. A bridge of the same type was reconstructed by the writer last summer, over the Youghiogheny River, at McKeesport, Pa. This bridge is 640 ft. long, with a 320-ft. middle span and two 160 end spans, and has a stiffening truss 10 ft. deep. The bridge is rigid enough to allow heavy electric cars to pass over it at full speed.

The East Liverpool bridge is very strong in appearance, though it had to be constructed economically. The contractors for this bridge were Jutte & Foley, of Pittsburg, for the substructure, and the Penn Bridge Co., of Beaver Falls, for the superstructure. Mr. E. S. Fickes, of Pittsburg, was resident engineer of the work.

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As our readers have probably noticed, the editors of Engineering News do not look with much favor on continued stories. We greatly prefer to make every article complete in the number in which it appears. On the other hand we are no great believers in cast-iron rules; and it occasionally happens that a paper of such interest to our readers that it demands presentation in full in our columns is of such length that it is impossible to publish it in one issue without making that number one-sided, or devoted too largely to a single subject. In such cases we are, of course, obliged to divide the paper and present it in parts in two or more successive issues.

It happens that two of the articles which are given in the present issue of Engineering News are necessarily treated in this manner. In one of these we have collected the standard designs in use by the principal railway companies of the country for locomotive turn tables. The drawings which accompany this article are so numerous and important that it requires two of our double-page inset sheets to properly display them, and this necessitates presenting the article in two separate issues.

The other paper to which we have to attach a "to be continued," is a paper by Mr. Dugald Clerk on Gas Engines, which we risk little in saying is the most important contribution to this subject outside of treatises especially devoted to it that has been made for many years. There has been a great demand for literature on gas engines for some time; and judging by some of the letters we receive, many engineers who are working in this field are in much need of information upon recent practice and on the controlling principles that should govern design. Mr. Clerk is one of the leading authorities of the world upon gas engines, and we believe our readers will find his paper of great practical value.

In technical literature a frequent source of ambiguity is found in the common method of describing the slope of earthwork embankments. According to a time-honored rule this slope is usually designated as "two to one," for example, with the further explanation, in some cases, that by this expression is meant a slope equivalent to one unit vertical and two horizontal. While the old expression is generally understood by engineers, without the further interpretation, it is often the cause of uncertainty to those not so familiar with engineering methods, and a clearer form of expression can be used. In the Corps of Engineers, U. S. A., it is now the common practice to speak of a similar slope as "one on two," with the result that a mental picture is formed of the actual slope that can not be misunderstood by any one. The old expression is meaningless in itself and is only justified by its long use; the later form of expression is much to be preferred and we would recommend its adoption by all engineers.

The Steam Users' Association, which was organized by Mr. Edward Atkinson, of Boston, something over a year ago, with great expectations, is dead. Mr. Atkinson announces the fact in a circular to the members, stating that the amount of the subscriptions for the continuation of the work is not sufficient to warrant the further undertaking. A final report by Mr. R. S. Hale, the engineer to the Association, is published along with the circular. It is quite brief and contains little information of importance to steam engineers. A note on "combustion in furnaces" contains some good advice for steam users in regard to one of the best means of economizing fuel in boilers. We quote from it as follows:

> The chief necessities are, an intelligent fireman and a means of letting the fireman know what economy he is attaining. Tests by experts are generally considered too expensive by owners of plants, although in two cases within the last month the gas analyses on expert's tests have pointed out the causes of evaporation that were 20 to 30% below the normal, and the changes in the method of firings thus suggested have made a proportionate saving. We strongly urge on all our members the use of some check on the economy. If the steam is used for power only, the indicator card may furnish such a check. If the steam is used for heating or manufacturing, a meter should be installed, with provision for calibrating it from time to time. If a meter for the whole plant is considered too expensive, a meter may be placed on one boiler, and this boiler used for testing coals or for testing firemen. A calibrated tank may be used instead of a meter. The use of meters, tanks or some such check is most essential where the load is variable, as where steam power is used to supplement water power.

Another good piece of advice is given in the following note on Boiler Heating Surface:

> Any attempt by salesmen to cut down the heating surface allowed per HP. should be looked on with great suspicion. Most makers now allow from 10 to 12 sq. ft. of water heating surface per boiler HP., and, though there will be no difficulty in developing the capacity on a less area, it can only be done at the expense of the economy.

Cast iron, its physical and chemical phenomena and their relations to each other, its proper treatment in the foundry, etc., are now frequently subjects of discussion in the engineering societies and in the technical press; but the experimental data produced and the theories thus far advanced cannot yet be said to resolve themselves into logical and scientific form. Our knowledge of cast iron, from the scientific standpoint, is in a most chaotic state, and it will probably be many years before enough is known about it to justify the writing of a treatise which will explain in clear terms the causes of the variety of physical phenomena which the metal presents. We are led to make these remarks by the perusal of a paper entitled "Phenomena of Cast Iron Investigated," in the March number of "The Foundry," "a trade journal devoted to the whole interests of the foundry business." We cannot say that the article has increased our knowledge of the phenomena of cast iron in the slightest degree, but it is interesting as an example of the kind of literature which in the minds of some readers passes for "science." We quote the following:

> In the subsequent explanation it will be taken as granted that atoms are vortex rings of the ether in the ether. * * * The effect of silicon in the presence of carbon in cast-iron has been long known. The action of silicon is catalytic, or, in other words, the field produced by the vibration of an atom of silicon so overlaps or neutralizes the field resulting from the union of carbon and iron that the mutual attraction of the iron atom and the carbon atom is so diminished that the carbon atom is set free. Since cohesion is due to gravitative action of a molecular rather than a molar kind, and chemism is also due to the same source, it is easy to see how this action of silicon is accounted for. * * * Consider two adjacent molecules of iron and iron carbide. Suppose the molecules to be separated the one fifty-millionth of a millimeter, which we will take as the diameter of the iron atom. Let the mutual attraction be represented by the one-millionth of a millidyne. Now suppose this molecule of iron carbide to be broken up, and consider again the attraction of the two iron atoms with the carbon molecule between them.

And so on, for several pages. The most remarkable thing about the article is that it ever found admission into so practical a journal as "The Foundry."

Our attention has been called to a typographical error in the paper by Mr. John D. Isaacs on "Preservation of Structural Timber," published in our issue of March 11, 1897. The process of Kyanizing was referred to in the paper as an impregnation with sulphate of copper. It should have read, an impregnation with corrosive sublimate" (bichloride of mercury).

A CHAPTER OF CURIOSITIES.

There has been long accumulating in the office of this journal a collection to which it is difficult to give a name. We sometimes call it "the crank drawer"; but "the wild-cat cage"-would be, perhaps, a more appropriate name. This drawer contains letters, circulars, newspaper clippings, etc., regarding some of the inventions and schemes that are constantly being brought to our attention which are interesting, not because of their merit, but because of their absurdity.

As this number of Engineering News is published on the first day of April, it has seemed to us an appropriate time to give our readers a glimpse of the contents of this drawer, in the hope that they may share in the amusement which we have found in the collection.

Near the top of the pile we find a collection of clippings regarding what probably deserves the palm as the master hoax of 1896, "The Brambel Rotary Engine." In November last telegraph dispatches were sent out announcing that Grant Brambel, a telegraph operator of Sleepy Eye, Minn., had sold to an English syndicate a patent on a rotary steam engine for the sum of $1,600,000 in cash. This item was published in hundreds of dailies all over the country, including the most reputable and conservative journals. Immediately afterward other dispatches announced that the total selling price was $6,000,000, which was later changed to $7,100,000. Of course such an item was a bonanza to the representatives of the "New Journalism," and also to that class of papers which are conducted to boom patent procuring or patent selling agencies. Representatives of these journals descended on the village of Sleepy Eye, and secured the whole story of the invention from the inventor himself, with pictures galore, from the inventor's physiognomy to the seven by nine house in which he resides, and not forgetting the engine itself, which, in its newspaper portraits, resembled a fat coffee mill with a tumor on top.

So much publicity was given to the matter finally, that several Western newspapers of reputation sent representatives to investigate the matter, and our contemporary, "The American Machinist," hunted up Brambel's rotary engine patent, and illustrated the engine with appropriate comments. The real facts of the case, as we gather from these investigations, were about as follows: Brambel did invent a rotary engine and obtained a patent upon it in 1895. The engine shown in this patent, is "far from the best and not far from the worst" of the many hundred rotary engines that have been invented, to quote with approval the "Machinist;" and the claim of the patent is one of the sort that covers everything and protects nothing. Brambel did build, in conjunction with one Prescott, a local machinist at Sleepy Eye, some sort of a rotary engine which was operated to drive the machinery in Prescott's shop. As for the story of the sale, from all the evidence collected, it appeared that an English "promoter" named H. F. Allan, who had been arrested for swindling in Minneapolis in 1891 and again in New York in 1894, was the "syndicate" to whom Brambel "sold" his patents. According to the Chicago "Tribune" Brambel created a similar sensation on a smaller scale at Skaneateles, N. Y., several years ago by announcing that he had sold a patent on an electric lamp for $70,000. But the evidence of his receipt of that sum was as evanescent as is the evidence of his receipt of the $7,000,000, more or less, from the "Allan syndicate." According to latest reports Mr. Brambel still continues to labor as a telegraph operator, and to live upon the salary which he derives from this work, in heroic disregard of the millions which he claims are lying to his credit in the banks of Chicago.

London and other cities. The village of Sleepy Eye has returned to its somnolent condition, and the representatives of the New Journalism are after some other hoax.

One amusing episode of the affair is told with highly appropriate comments in the following extract from the New York "Times":

Grant Brambel, the telegraph operator at Sleepy Eye, Minn., who claims to have invented a rotary steam engine of remarkable, not to say supernatural, efficiency, and to have sold it to an English syndicate for millions more or less numerous, has taken offense at the incredulity with which his yarns have been received. Moved by this feeling he has caused the following savage menace to be printed in the advertising columns of one of the village papers:

"To all concerned: Our personal matters that are so much talked about must cease at once, or it will be placed in proper hands of the law."

As among the "all concerned," having expressed reluctance from the very beginning to number Mr. Brambel among the world's great inventors, we have naturally read this notice with grave attention, and it is only fair to confess that it has changed our opinion of him materially. The man ungenerous enough to write English so unlike that in common use may well have constructed a motor that ignores the laws of physics. The Wizard of Sleepy Eye has vindicated conclusively his right to be considered an original thinker; that is, he thinks spirally. Probably his engine works in the same way, and, owing to that peculiarity, has wormed itself off somewhere into the fourth dimension, out of sight of the impertinent machinists who spend their time in deriding it and its inventor.

Every great genius has his imitators. The great publicity given to Brambel and his inventions brought other inventors of a similar sort to light. The Boston "Herald," of March 8, contained a report that a rotary engine had been invented by one Frank Reynolds, of Lewiston, Me. We quote from that journal as follows:

When the announcement was made that Grant Brambel had sold the patents of his engines for millions, Mr. Reynolds was startled. He had been working a long time on his idea, and while he was reading the account of the Brambel invention he trembled like a leaf, and cold sweat stood out on him like beads. Then he breathed easier. Brambel's was not his idea. He yet had his scheme to himself, and it was better, he claimed, than a dozen like that of Brambel.

Side by side with any of the other rotary engines which have been invented, this one of Reynolds' shows superiority at a glance. It is as simple as the alphabet, but has a power of herculean proportions. The model which Mr. Reynolds shows is so small that it can be put into an ordinary coat pocket. It is about as large around as a common saucer, and less than 2 ins. thick. The piston is 3 ins. in diameter and 1 in. thick, and yet this model, attached to a boiler with 100 lbs. of steam to the square inch, at 3,000 revolutions to the minute, produces 13 HP.

A test of the model of this engine, which a child can hold in its hands, developed, with 1,500 revolutions per minute, 6 9-11 HP., and with 10,000 revolutions per minute, the power of this liliputian engine will equal 42 HP.

Wonderful claims are made for this engine, and it is said it will revolutionize the steamship business of the world. The Allen syndicate purchased the Brambel engine with the hope that it would largely decrease the expense of running its steamship lines; but while a Brambel machine, which is being tested in Trenton, N. J., has 250 HP. the assertion is made that a machine of the same size, built on the Reynolds' plan, would have 5,000 HP., or 4,750 greater than that of the western invention.

By the same token, if Brambel's engine is worth $7,000,000, Reynolds' must be worth $140,000,000, or else our mathematics are all astray.

Before leaving Brambel, a word of comment may be made on the injury which the newspapers do by giving publicity to such foolish reports. The story of Brambel's fortune was heralded far and wide; the fact that it was all a hoax was told by not one in ten of the papers that originally published the story. Probably millions of credulous ones will always believe the story of Brambel's riches, and it is just such beliefs as these that keep multitudes of ignorant and uneducated men and women infatuated with the idea that they, too, can win fame and fortune by making some marvelous invention. Scores and hundreds of men wreck their lives in pursuit of some will-of-the-wisp invention, which they are wholly incompetent to perfect, and which would be of no commercial value if it were perfected.

Minnesota appears to be a prolific field for inventors of the class who propose to revolutionize things. One J. G. Kaller, of Mankato, according to a press despatch dated Dec. 31, 1896, has invented a hydraulic motor, which is really a perpetual motion scheme. The description is as follows:

The principle upon which it works is the natural law which causes substances lighter than water to rise to the surface. An endless chain of small air-tight tanks is placed over two sprocket wheels in such a manner that on one side it will pass upward through a large tank of water. As each air-tank enters the water tank from below through a water-tight valve, it will be forced to the surface by the superior weight of the water, and in this way the chain will be kept in perpetual motion, revolving the sprocket wheels, to which shafts are attached. Thus, if the claims of the inventor are true, the motor will run on indefinitely without fuel.

Some of our readers will find it an instructive exercise in analytical mechanics to examine this scheme and find just where the fallacy in it lies. Mr. Kaller, according to the dispatch, had gone no further than to apply for a patent. He will probably be disappointed about this time to learn that the Patent Office rejects on principle all inventions which involve perpetual motion.

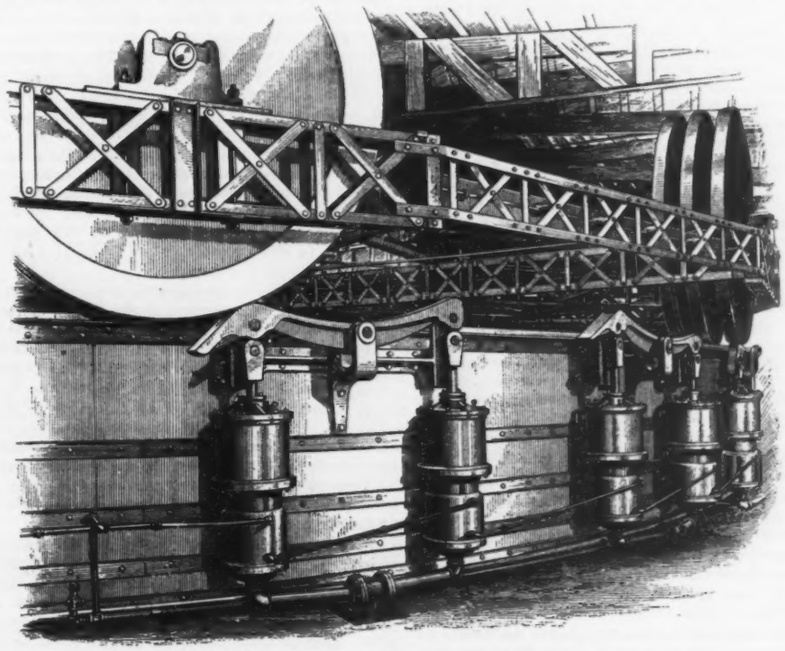
Another perpetual motion inventor who carried his ideas to the extent of actual construction is one E. Chaquette, who built, a year or so ago at Bridgeport, Conn., about the hugest specimen of engineering absurdity of which we have ever heard. This machine was an air compressor of exceedingly peculiar design, which was to be driven by two steam engines of 70-HP. each, and was to compress air to a pressure of 100 lbs. per sq. in., in quantity sufficient to develop continuously 2,500 HP., thus multiplying the power about 18 times.

The mechanism by which this was to be accomplished was such a curiosity that we have thought it worth while to reproduce an illustration of a portion of the machine as published in the "Iron Age" of July 23, 1896. The apparatus consisted of an enormous horizontal wheel, 80 ft. in diameter, with ten spokes and a rim built of latticed struts. Where each spoke met the rim, was journaled a heavy cast-iron wheel 9 ft. in diameter and with a total weight of 13½ tons. This wheel was made with three treads, the central one running on a circular stationary track like that for an ordinary bridge turn table, and the other two adapted to operate treadles or levers located around the outside and inside of the track, as shown in the sketch. The 70-HP. engines were located at the center and were to make the whole apparatus rotate. The total number of compound air compressors was 100, with cylinders 12 and 16 ins. in diameter. We quote from "The Iron Age" the following explanation of the principles involved:

The operation of the machine will be readily understood. If the wheel should make ten revolutions per minute, there will be 100 impulses or strokes of the air compressors at each revolution, and 10,000 for the ten revolutions it is expected to make in each minute. Knowing the capacity of each compressor, it therefore becomes a mere matter of calculation to ascertain the power developed and made available, as air under pressure, if the wheel could be run at ten turns per minute. Taking into consideration the actual power applied at the center to turning the wheel, the multiplication expected is something tremendous. As stated by Mr. Chaquette to our representative, it is calculated that of the total power developed, only about 4½% will be required for the actual turning of operation of the wheel, and that the remaining amount, or about 95½%, will be available for commercial purposes. The momentum of the wheels carried at the ends of the arms or spokes, their great weight compared with the work they are expected to perform, and the constantly increasing leverage of their action upon the several rocker levers, are depended upon for the successful operation of the machine. It may be added in conclusion that the machine has been protected very completely by letters patent issued to Mr. Chaquette.

If the latter statement is true, it is safe to conclude that Mr. Chaquette's attorney did not insert the inventor's claims to the multiplication of power in his patent. Of course there would be nothing to prevent his obtaining patents galore on details of his peculiar machine.

Another inventor who proposes to multiply power is Benjamin C. Pole, whose office is at Room 53, Atlantic Building, Washington, D. C., and whose works, according to a circular before us, are at Deanwood, D. C. Our knowledge of Mr. Pole's invention is gained not only from his published circulars but from a personal interview with the gentleman himself which took place several months ago. Mr. Pole's scheme is as follows: Upon the main shaft of an ordinary steam engine he mounts a heavy flywheel, and connects it to the shaft by a friction clutch. This friction clutch is operated by a mechanism which automatically disconnects it from the shaft, when the engine is passing over the 90° nearest to the ends of its stroke and connects it again during the 90° of the revolution nearest to the midstroke position of the engine. To the ordinary mechanical mind, there might seem to be no end to be gained by this complicated procedure; but Mr. Pole assured us that by this arrangement he was enabled to take off about twice as much power from the large fly-wheel when propelled in this fashion as was developed in the engine that drove it. In our conversation with him he appeared to be possessed with the idea, which has deluded hundreds of inventors, that the crank motion, by which the reciprocating action of the steam engine is changed into rotary motion involves some loss of power. However, when he was asked whether if an electric motor were used to drive the fly-wheel, his alternating clutch arrangement would multiply the power just the same, he unhesitatingly assured us that it would. As an example of Mr. Pole's arguments in favor of his device, we reprint herewith verbatim the following extract from one of his circulars:



VIEW OF OUTSIDE OF TRACK OF THE CHAQUETTE AIR COMPRESSING MACHINE.

MOMENTUM ENGINE.

TO POWER USERS.

"Economy is Wealth."

Fifty per cent. saving of coal by using the "Energizer" on your Engine.

This Attachment Placed on All Makes of Engines.

This result is obtained by the addition of the law of acceleration. The engine has two dead centers and two live ones, and by means of an automatic device the engine is detached from the work while at the live centers and connected while at the dead centers.

The flywheel is about four times as heavy as the ordinary engine flywheel, and by disconnecting the engine from its load the law of acceleration takes place and is absorbed into momentum, and thence into power.

The engines used heretofore use their energy of the pis-

ton directly into the work, but not with the efficiency of the Energizer Engine.

Like unto the injector, the energy of the steam is not the only force that places the water into a boiler. It is the vacuum, which is in addition to the force of the steam which accelerates the motion of the water, and the combined force of the steam and vacuum and the momentum of the water produces the result well known by all.

The steam alone will not work the injector, and the vacuum alone will not work it; and so the combined forces produce the result.

Infringements will be prosecuted.

The American Energizer Mfg. Co., Ltd.

Any one might naturally suppose that a contrivance which would successfully multiply the power of a steam engine by two would be a certain success; but circulars of a later date indicate that Mr. Pole for some unexplained reason ceased to push his "energizer" attachment, adapted for all forms of engines, into public notice, and devoted his attention to an "energizer gas engine" operated on the same principle—or lack of principle. In still another circular from the same source we learn that a gas engine with the "energizer engine" device has been placed on a street car and the National Street Car Motor Co. has been formed, capitalized at $500,000, divided into shares of one dollar each. In this circular the claims to multiplication of power are notably absent. It is, of course, possible that with a good gas engine and a good friction clutch mechanism for disconnecting the engine when the car stops, Mr. Pole might construct a very respectable street car motor. A brief account of a test of this street car motor was published in our issue of Sept. 24, 1896.

We trust that Mr. Pole has not abandoned his claims to the multiplication of power. Robbed of this feature his invention loses its picturesqueness and becomes commonplace.

But though Mr. Pole's energizer should cease to energize, there will still be others. A Southern inventor, one A. H. Beard, has developed an electric motor which has the pleasing faculty of giving out more energy than is put into it, if the Atlanta "Journal" of Dec. 26, 1896, may be believed. Mr. Pole explained the principle of his invention by the use of mechanical terms. Mr. Beard soars into the realm of electricity and explains that his motor accomplishes its results "by the utilization and the harnessing of two forces to one engine, i. e., the inducing and the induced, the developing and the developed, or both the kinetic and potential energy of the sun's rays"; it is "achieved" principally by the "utilization of one-half of the momentive force each of two electrical currents over copper wires," and it is "harnessed by the convention of a series of infringed attractive rachet forces," etc. The inventor invited "the immediate attention of electrical engineers, scientists, manufacturers, capitalists and speculators to come and witness, test and measure the working results of the working model."

It will be noted that the Chaquette machine was to multiply the power put into it 18 times. Mr. Pole was content in his published circulars to double the original power, although he privately assured us that he could actually multiply the power 10 times if necessary. Mr. Beard claimed only to increase somewhat the original power applied to his motor, and yet we confess his explanation is the most transcendental of the lot.

A very attractive field to inventors of devices of the class we are discussing is that of marine construction, and means of propelling boats and vessels. Among the most entertaining volumes in our library of curiosities are the "treatises" on marine propulsion which were written and published nine years ago in defence of the Jackson jet propulsion system, by the inventor and his chief lieutenant. The high-sounding arguments in these books are especially interesting now after the fallacy of the scheme has been shown by the test of practical trial. One passage in these books has become especially impressed on the writer's memory, partly because of its lofty grandiloquence and partly because it was such a favorite with the inventor that he frequently brought it in in his newspaper interviews. We quote it as follows:

It is truly flattering to one's vanity to have his theory praised and endorsed by men whose order of special fitness would not enable them to understand the system in all its refined detail if they studied it exclusively for a century. I have not blundered upon a discovery, or fallen from the tenth story of a building into a supposed gold mine. My conclusions are based on a strict, scientific analysis of cause and effect. I did not dream out any of my coefficients, or receive my conclusions by virtue of any special inspiration; simply faithful, systematic thought, stimulated not by a desire to make money, but by a determination to learn the truth.

The wide publicity which was given to Dr. Jackson's jet propulsion scheme had the effect of starting numerous other inventors at work upon similar lines. One of these was Alexander Vogelsang, of 177 Montague St., Brooklyn, N. Y. His scheme, as described in the Brooklyn "Eagle," was to use a small jet, under high pressure like Dr. Jackson, but to attach the jet or jets to a rotating disk so that it would continually "find a new and virtually unmoved body of water to strike against." According to the clipping from which we gain our information, the inventor had tested his scheme on a vessel of about 90 tons and "a syndicate" had been organized to fit a ship of over 2,000 tons with his appliances. We have never heard of it since, however.

Many inventors of the class of which we write are possessed with the idea that the Government should do something to aid their chances to success. They haunt the committee rooms of Congress and buttonhole Representatives and Senators at every opportunity. One Richard H. Painton, not many months ago was granted a hearing by the Senate Committee on Naval Affairs, and Senator David B. Hill introduced a bill authorizing the Secretary of the Navy to construct cruisers on Mr. Painton's designs. The proposition of this inventor was to range a lot of small screw propellers along each side of a vessel. In a small model, which he exhibited, he had placed seven on each side. He proposed to drive these screws by electric motors, one for each screw, taking current from dynamos driven by the main engines of the vessel. Besides propelling the vessel, the screws were to preserve its equilibrium and prevent it from rolling; and vessels built on this plan, according to the inventor, were to make speeds of 35 to 40 knots per hour.

Another scheme for vessel propulsion which was exhibited in the basement of the House of Representatives nearly ten years ago was the Bender propeller, the invention of Henry C. Bender, a German carpenter of Montgomery Co., Pa. This propeller was a paddle-wheel placed on the bottom of the hull amidships, instead of at the sides or stern. The wheel revolved in an air-tight chamber, which was supposed not to fill with water, though for the most part it was below the water line. A newspaper clipping before us declares that this "is really one of the greatest inventions of even this Nineteenth Century era of inventions."

A much more abnormal mode of marine propulsion was recently brought forward by James Gresham, of 440 State St., Brooklyn. His "boat" is shaped like a cylinder with conoidal ends, and a steel flange runs spirally around it from end to end. This cylinder is caused to rotate on its axis and the spiral flanges, of course, push the cylinder forward through the water. Inside this revolving cylinder is another stationary cylinder in which the freight—and possibly the passengers—are placed. Bent pipes from this interior stationary cylinder project at each end and are turned upward and form the axles on which the outer cylinder revolves. These pipes are the only means of communication between the interior cylinder and the outer world. We believe Mr. Gresham's ideas never reached practical expression in any more extensive shape than a three-foot model.

Compared with the above scheme the next one before us is a very sensible contrivance. This is a plan for propelling vessels by compressed air, which is furnished by the rolling and pitching of the vessel itself. We quote the following description from the Philadelphia "Telegraph" of Oct. 10, 1896:

The apparatus is said to be particularly adapted to freighters and other slow sailing vessels, and may be used as an auxiliary to sails or steam or may be independent of both. The motion imparted to the ship by the waves is utilized for compressing air, which then is introduced into the cylinder of an engine connected with a propeller shaft, and to insure motive power when the vessel is in smooth water a steam boiler is recommended.

The hull is of the usual construction, except that it has a swinging tank having a capacity of from one-third to two-fifths of the vessel's carrying capacity. The tank is made strong and tight and is weighted with a part of the cargo, or when the vessel is sailing light, may be filled with water or other ballast. The tank is mounted on universal or gimbal joints journaled in a swinging yoke extending around it; the yoke has trunnions opposite each other in bearings on the sides of the hull. The forward and after side walls of the tank have trunnions journaled in the yoke, the two sets of trunnions being arranged in a horizontal plane and at right angles to each other. Thus the oscillations of the vessel proper within fixed limits are not transmitted to the weighted tank—the latter remains level with respect to the rolling and pitching of the hull.

There are two sets of air-compressing machines. The forward compressor utilizes the rolling motion, and the other is actuated by the pitching of the boat.

This scheme was covered by patents issued to Geo. W. Price, of Providence, R. I., and the Ocean Power Propeller Co. was organized in that city to exploit the invention. It is fair to say that while practical difficulties may very likely prevent the success of this idea, it does not involve any theoretic impossibilities as do most of the schemes which we have described above.

The next invention on our list is the idea of another Brooklyn man, one Reuben H. Plass. As described in the Washington "Star" of Jan. 9, 1897, Mr. Plass proposes to build a war vessel in three sections of about equal length, joined to each other by vertical axes, so that either end can be deflected to right or left, by suitable machinery under the control of the pilot. The end to be gained is merely the rapid manoeuvring of the vessel in action. By deflecting the bow and stern sections until they each make an angle of about 30° with the axis of the midship section, Mr. Plass expects to make his vessel turn from full speed in a circle of its own diameter.

We will conclude our list of wonderful inventions in marine construction with some notes concerning a vessel upon which a great amount of money was expended, the "Howard Cassard." This vessel was built to carry out the ideas of Mr. Robert Freyer, of Alexandria, Va., by the Monumental Construction Co. of Baltimore. The vessel was popularly called "the arrow steamer," and her designer's idea was to make her so long and narrow and supply her with such a great amount of power that a speed of 30 knots per hour would be obtained. The hull was 206 ft. long over all; the beam was only 16 ft., and the depth was the same. Stability was secured by the use of an enormously heavy iron keel. The screw was 10 ft. in diameter with a pitch of 15 ft., and was driven by an engine with two 30-in. high pressure cylinders and two 60-in. low pressure cylinders, all having a stroke of 2 ft. These cylinders were placed side by side as near the keel as possible, and with their stroke vertically upward. The piston rods operated rock shafts, directly over the cylinders, and arms on these rock shafts were connected by rods to cranks on the propeller shaft. The engines had Corliss valves, and these refused to work when the engines were tried and men had to be stationed to move the valves by hand. After the vessel had been completed according to Mr. Freyer's designs, the engines and propelling machinery proved such complete failures that a consulting engineer, Mr. H. A. Ramsay, was called in. He substituted a link-motion valve gear as the best that could be done under the circumstances and made such improvements as were possible. After these were carried out the vessel had her trial trip and attained a speed of 15 miles per hour instead of the 30 knots which the inventor had promised. Thus ended the session of another class in the school of experience.

In the field of aerial navigation inventors have not been so numerous in recent years. About the time when E. J. Pennington floated the "Mt. Carmel Aerial Navigation Co., capital $20,000,000," into public attention, inventors of flying machines turned up every week. The latest, and about the only flying machine scheme that has come to our notice recently was set forth in the Chicago "Journal" of Jan. 23, 1897. According to this, Oscar D. Booth and W. H. Cotton are building in a shop on West Madison St., Chicago, an air ship which consists of a cigar-shaped "buoyancy chamber" from which a car is suspended. The vessel is propelled by a gasoline engine which weighs only 250 lbs., and develops 10 HP. According to the press report, a trial trip was to be made in two weeks; but we have yet to hear of its occurrence. Of course, there is nothing new in the scheme. "dirigible balloons," as they are called, were experimented on and developed to about as high a degree of perfection as they are capable of years ago.

So we might continue, to an indefinite extent, before exhausting the contents of our "Crank Draw-

er." Here we have records of such wonderful schemes as Wm. Dallin's air line railway from New York to San Francisco, the late Brick Pomeroy's Atlantic & Pacific tunnel, which was to pierce the "Continental Divide" in Colorado, and develop enormous quantities of (hypothetical) gold and silver ore. But we have given enough to show the reader something of the curiosities in the field of invention and promotion which are all the time coming into prominence; and which, thanks to the craze for sensation which affects the modern newspaper press, passes in the popular mind for evidence of the world's progress.

It may seem strange that in these days when educated and trained engineers can be found everywhere thoroughly competent to give advice respecting the soundness of investments in such schemes as we have been describing, such enterprises as some of those which we have described should be able to draw thousands of dollars from the pockets of investors. One thinks of Barnum's famous saying, "the American people like to be humbugged." But although it may seem on the surface that popular education and scientific training had been of no influence in this field, it is not really the case. The perpetual motion machine is much less common now than it was a half century ago. With perhaps one notable exception, men no longer study out schemes for the transmutation of metals. The promoter of a mechanical absurdity finds his task far harder than it was in the days when scientific education was unknown, and there was no engineering profession. Probably there will always be inventors of the crank class, promoters who had rather float a scheme of the Col. Sellers' order and gullible ones to be victimized; but the great mass of people are gradually learning that something cannot be made of nothing, and that expert advice is the only safe guide to profitable investments in new enterprises.

LETTERS TO THE EDITOR.

Disagreeable Effect on Railway Curves.

Sir: In Wellington's "Economic Theory of Railway Location," p. 272, the formula,

$$V = \frac{58.536}{\sqrt{D}}$$

is derived for the velocity (V) in miles per hour that will bring a passenger car body level on a D° curve, on the assumption that the elevation (E) is ½-in. per degree of curve, and that the weight (W) of the car body compresses the springs 6 ins. on a level.

(1) If the car body is still, on an inclined track whose elevation of outer rail is E inches, the weight (W) line will cut the axle about E inches from the center. If the car body is brought level the outside spring must be compressed ½-E inches, and the inner released that amount.

$$\text{Centrifugal force (C)} = \frac{W\,V^2D}{85666}.$$

Compression (P) on spring to bring car body level is

$$P = \frac{E\,W}{24} = \frac{W\,D}{48}.$$

Assuming according to Wellington that the lever arms of the couples P and C are equal, we have:

$$P = C = \frac{W\,D}{48} = \frac{W\,V^2D}{85666} \quad \therefore V = 42.2.$$

The velocity is therefore independent of the degree of curve if the elevation is a certain constant fraction of D.

(2) If we allow for the extra compression on the inner spring due to the inclination of the road-bed, the inner spring carries $\frac{W}{2}\left(1+\frac{E}{60}\right)$ and the outer $\frac{W}{2}\left(1-\frac{E}{60}\right)$ assuming the distance between the springs 60 ins. The inner spring will have to rise $\frac{7\,E}{10}$, and the outer fall the same amount.

Then

$$P = \frac{7}{120}E\,W = \frac{7}{240}D\,W, = \frac{W\,V^2D}{85666} \quad \therefore V = 49.98.$$

(3) For all curves over 16°, when the elevation is limited to 8 ins. (Wellington, p. 298), we have

$$V = \frac{168.98}{\sqrt{D}}.$$

Wellington's formula is not true according to his own data unless an elevation of ½-in. is assumed for all curves.

Thos. U. Taylor.

University of Texas, Austin, Tex., March 10, 1897.

Tests of a Cahall Boiler at the Armstrong Cork Works, Pittsburg, Pa.

Sir: We note a criticism in your editorial columns in the issue of Engineering News of March 18 of a test made by Thos. Pray, Jr., on a Cahall vertical boiler at the Armstrong Cork Works. There are a few suggestions and corrections we would like to have you consider concerning this criticism of yours, and as the criticism as published has attained a wide circulation, we naturally would like you to publish our comments thereon.

To begin with, after the general statement that the results obtained in this test were impossible, when you begin definitely to attack the test your first word is "assuming." Now, assumptions are somewhat dangerous in matters of this sort, and are very apt to be misleading. Your first assumption is that 20 lbs. of air are used per pound of coal burned. You give this assumption in a way that would lead the non-discriminating reader to accept it as a proven fact. We wish to dispute this at the outset. We have before us a series of 34 analyses made of escaping gases from Cahall vertical boilers in connection with which careful measurements of air were made, and the average air used in these 34 tests, is a little less than 15 lbs. to the pound of coal burned. Therefore, by your formula for calculating the heat units lost in the chimney gases (as our average in these 34 tests is only 75% of your assumed quantity of air used), the average losses in heat units in escaping gases is only 75% of the 13.01% loss figured in accordance with your assumption, or a loss in escaping gases of 9.76% instead of 13.01% as estimated by you. As the test shows a total loss of 14.14%, and as the loss through escaping gases is probably 9.76%, we have a surplus of 4.38% unaccounted for to cover incomplete combustion and radiation. You "assume" again that this radiation can be scarcely less than 3%, and that the losses from incomplete combustion should be at least as much more, two assumptions that are entirely unwarranted and have no business to enter into such calculations unless you have definite grounds through test and experiment with the type of boiler under discussion to show conclusively that these losses in repeated trials have amounted to as much as you have estimated. Even then, there would be no certainty that your assumption was correct, for the reason that the particular case under discussion might have differed by 1½% from the general average very easily owing to extra precautions being taken against radiation and incomplete combustion.

You further go on to state that the calorimetric determination of the Summer Hill coal in this test is "probably incorrect" and you base your reasons for this statement on the general announcement that that determination with a coal having 18.18% of ash would be equivalent to 15,700 B. T. U. per lb. combustible, which you think is an extraordinary value for any coal in the vicinity of Pittsburg. In reply to this we attach an analysis of coal from the Pittsburg district showing a higher thermal value per lb. combustible than the 15,700 heat units you mention:

Proximate Analysis.

	Per cent.
Moisture	1.29
Volatile combustible matter	35.96
Fixed carbon	54.35
Ash	8.40

Ultimate Analysis.

	Per cent.
Moisture	1.29
Carbon	75.85
Hydrogen	6.57
Oxygen	5.70
Nitrogen	1.28
Sulphur	0.91
Ash	8.40

British Thermal Units by Mahler, 14,816 per lb. of coal, or 16,174 per lb. of combustible. In many of these coals a considerable percentage of hydrogen is found, which raises the thermal value very rapidly, as you know. The determinations on the Summer Hill coal were made for Mr. Pray at Cornell University. Three samples and three determinations were made and the average of the three taken as the proper figure. It is therefore fair to assume that the people at Cornell gave us results which were approximately accurate. You state that the Summer Hill coal used in test No. 2 contained only 5.33% ash. You have no ground for this assumption. The refuse weighed in at the end of the test amounted to 5.33%, but as test No. 2 was made by the owners of the boiler with their ordinary fireman without exercising any great care as to results, a large portion of the fine ash could have escaped with the chimney gases. This is especially true as the Hawley furnace was attached to the boiler during all these tests, and by improper manipulation of the firing doors on this furnace a very large percentage of the fine ash can always be carried off through the stack and no credit obtained therefor. Test No. 7, the one you take, was on the contrary fired by an expert and all minor points carefully looked after. The very fallacy of your reasoning in comparing these two sets is proven by the fact that your ultimate result shows that in accordance with your method of figuring, the coal used in the test No. 7 would only contain 10,743 B. T. U., whereas as stated before, the determinations made at Cornell showed that the coal actually contained 12,854 heat units, or about 20% more heat units than your assumed results give.

The actual point of result to be considered in a test of this sort is the percentage of efficiency shown. In the test attacked by you the efficiency is a little less than 80%, which we know to be not only possible with the boiler under discussion, but a result that we can under proper conditions obtain very frequently. Test No. 2 itself, which you use as a comparison with test No. 7, shows an efficiency of very nearly 82%, although the boiler in test No. 2 was run under ordinary conditions with an ordinary fireman. And it is not straining a point to assume that a boiler which tested under ordinary conditions will show an efficiency of 82%, will, under test conditions with expert fireman, show the additional 4% obtained in Pray's test, especially in view of the fact that in Pray's test the boiler was run only 3% above its rating while in test No. 2 it was run 11% above its rating. Test No. 5 published by you in this article, which was also run under ordinary working conditions, showed an efficiency of 79.01% with the boiler running 32% above its rating, which is certainly as satisfactory an efficiency as 85% would be with the boiler running down to about its normal capacity.

The thing that seems to surprise you most, however, is the claimed evaporation of 13.96 lbs. of water from and at 212° per pound of combustible, and if assumptions are to be dealt with, let us assume a case under which an evaporation of this sort would be possible. Suppose for instance, that you had a coal running 10% or even lower in refuse, but which contained 7 or 8% of hydrogen. Now, suppose that this coal was so burned that the hydrogen was all burned and that the combustion of the carbon burned was practically perfect, but that in addition to the 10% natural refuse in the form of incombustible matter, 8% of the fixed carbon fell through the grate bars in the form of incandescent coke, and was weighed back as refuse, you would have utilized all the hydrogen with its enormous calorific value, and would have lost nothing but the actual weight of carbon unconsumed. Would this not give an apparent evaporation, in pounds of water per pound combustible burned, much higher than is ordinarily deemed probable. Of course these percentages of fixed carbon unconsumed and hydrogen present in the coal originally can be juggled with at will, so that almost any results desired could be obtained, if one goes into the realm of "assumption." For instance, you might assume that only the hydrogen was burned out and all the fixed carbon was weighed back in the form of refuse.

We deplore a spirit of criticism in a journal as widely read by influential people, as yours is, which attacks a test made by an engineer of national repute, presumably under honest conditions, the whole basis of the attack being founded on mere assumptions of things that might have taken place under some other conditions with some other boiler in some other place at some other time. "The proof of the pudding is in the eating of it," and we are prepared and willing to demonstrate that the percentage of efficiency obtained in this test is not only possible but can be duplicated in the same plant and on the same boiler on which the test under discussion was made.

Yours very truly,

Cahall Sales Department,

W. C. Temple, General Manager.

Bank of Commerce Bldg., Pittsburg, Pa., Mar. 26, '97.

(We assumed a consumption of 20 lbs. air per lb. of coal in the belief that that is as small a consumption of air as is feasible with Pittsburg coals, burned in a boiler furnace, without introducing considerable losses from imperfect combustion. If our correspondent can burn Pittsburg coals with only 15 lbs. of air per lb. of coal on the average, and without losing considerable of the calorific power of his fuel through imperfect combustion, he is accomplishing a feat worth putting on record and we hope he will send us the detailed record of the tests for publication.

We are glad that our correspondent has answered in detail the points which we raised in our original discussion; for we always prefer in this journal to have both sides of a disputed question fairly presented, regardless of what our own views and opinions may be. We are content also to grant him the last word in the discussion, so far as percentages of ash, calorific efficiency, etc., are concerned, and rest our side of the case on our original discussion.

The last paragraph in his letter, however, we propose to answer. He "deplores a spirit of criticism" in this journal. But that spirit is just what we are aiming to cultivate. Anything which will not stand honest criticism ought to go down. It is our aim so far as possible to be just as faithful and conscientious in pointing out the weak points in a machine or a test or a book, as the good ones.

He states that our whole basis of "attack" was founded on mere assumptions, etc. As a matter of fact, we criticized tests of other boilers in the same article; and our arguments were by no means based on assumptions. Our position is briefly this: Every engineering test or measurement is subject

to a greater or less percentage of error. A test of the efficiency of a steam boiler is subject to a very considerable percentage of error, and this percentage is especially great when calorimeter tests of coal are a factor in the determination. In the especial case of the Cahall boiler, five tests on the same boiler were published, of which four were very close together, and gave an average result of 11.492 lbs. of water evaporated per pound of combustible. The fifth gave a result of 13.968 lbs. per lb. of combustible. We believe that under such conditions doubt is necessarily thrown upon the accuracy of the fifth test; and the fact that the boiler was run at a lower rate of evaporation does not seem to us sufficient to explain the difference.—Ed.)

RECENT DEVELOPMENTS IN GAS ENGINES.*

By Dugald Clerk, Assoc. M. Inst. C. E.

In the year 1882 the author submitted a paper dealing with "The Theory of the Gas Engine,"[1] in which the several inventions were classified into a few principal types. The theory of the action and efficiency of the respective types was established, and has since been fully demonstrated, while the "stratification" theory has vanished.

Great advances have been made since 1882 in the construction and efficiency of gas engines, and the power developed by them has increased; so that the best gas engines are now, both from the mechanical and the heat-engine standpoint, highly efficient machines. Many new engines have appeared, but all belong to one or other of the three types then classified: 1st, non-compression engines, igniting at constant pressure (no explosion); 2d, compression engines, igniting at constant pressure (no explosion); and 3d, compression engines, igniting at constant volume (explosion).

For practical purposes, engines of the first two types may be disregarded; non-compression engines are now considered to be much too wasteful of gas to be of commercial importance; and compression engines of the second type have not advanced beyond the stage attained by Brayton. The expectations of the late Sir William Siemens, in which the author shared, with regard to this type of compression gas motor, have not been realized; and whatever may be the future of the constant-pressure hot cylinder regenerative gas engine, at present there is no sign of its development as a rival to the compression gas engine of the third type.

All gas engines now constructed belong to the third type. They are "engines in which a mixture of gas and air is compressed or introduced under compression into a cylinder or space at the end of a cylinder, and then ignited while the volume remains constant and the pressure rises. Under this pressure the piston moves forward, and the return stroke discharges the exhaust." Mechanically considered, such engines may be broadly divided into:

(a) Engines working in accordance with the Otto cycle, in which one cylinder fulfils alternately the functions of pump and motor, so that only one impulse may be obtained for the two revolutions of the crank-shaft.

(b) Engines having a separate pump or other charging device, by which a charge is compressed in, or introduced in a compressed state into, the power cylinder, and one impulse may be obtained for each revolution of the crank-shaft.

Engines working on the Otto cycle have proved by the test of experience to be the best adapted, of all the engines yet invented, to present needs; and their deserved popularity has gradually led to the extinction of all other types. Good results have, however, been obtained from engines giving an impulse at every revolution, most of which, both in England and on the Continent, have followed the Clerk cycle; but from various causes such engines have not kept pace with the Otto cycle engines, and so at present nearly all the engines manufactured in England are of the Otto type.

The mechanical development of the engine will be evident from the consideration of a Crossley Otto engine built thirteen years ago, and of a recent engine delivered in 1892 (Figs. 4 to 9), but it may be instructive to deal first with the advance in efficiency from the point of view of economy in the consumption of gas.

In the great majority of Otto engines, during the first forward stroke of the piston, gas and air stream into the cylinder from the beginning to the end of the stroke, the charge mixing as it enters with whatever gases the compression space may contain; the return stroke then compresses the mixture into the compression space, and when the piston has attained its full stroke and the compression is completed, ignition takes place, and the piston moves forward under the pressure of the explosion. The next instroke is the exhausting stroke. The gases thus expand after explosion, doing work on the piston, and the expansion terminates when the gases have attained the volume which they occupied in the same cylinder before compression commenced.

It has been shown by the Author that an air-engine supposed to carry out this cycle of operations perfectly (i. e., assuming no loss or gain of heat in any of the operations, no changes of temperature except by the addition of just the necessary heat to attain maximum temperature, and the fall of temperature being due to adiabatic expansion only while the compression line also follows the adiabatic curve) has an efficiency entirely independent of the maximum temperature of the gases. Increase of the maximum temperature raises the indicated power of the engine, but does not increase the heat efficiency, or the fraction of heat converted into work.

In the Author's previous Paper,[1] the duty or efficiency, D is given as $D=\frac{T-T'}{T}$, where T' is the absolute temperature of the air in the cylinder before compression, and T is the absolute temperature after adiabatic compression. Where t is the absolute temperature of the gases in the cylinder before compression,[2] and t_c is the absolute temperature after adiabatic compression—

$$E = 1 - \left(\frac{t}{t_c}\right) \qquad (i)$$

or more conveniently

$$E = 1 - \left(\frac{V_c}{v}\right)^{y-1} \qquad (ii)$$

Where E is the efficiency, v is the total volume of the cylinder and compression space, and V_c is the volume of the gases in the compressed state. The formula (ii) enables the theoretical efficiency to be at once calculated, provided that the relative capacities of the compression space and the volume swept by the piston be known.

Considerable advance has been made in engines of the Otto type with regard to economy in consumption of gas since 1882; at that time, the lowest consumption of gas recorded as the result of independent tests was 22 cu. ft. per I.HP. per hour, as determined with Glasgow gas by the Philosophical Society of Glasgow on an engine of 8 nominal HP. In 1881 experiments were made with a 12 nominal HP. engine at the Crystal Palace Electrical Exhibition, showing a gas consumption of 23.7 cu. ft. per I.HP. per hour; and up to the beginning of 1888, the consumption does not appear to have been appreciably altered. In May of the latter year, the Author made a careful test with a 9 HP. Otto engine, No. 8705, built by Messrs. Crossley, which consumed 23.98 cu. ft. of Birmingham gas per I.HP. per hour. Corresponding consumptions of Glasgow and London gas would be 22.0 and 23.7 cu. ft. per I.HP. per hour. A diagram taken from that engine is shown in Fig. 1.

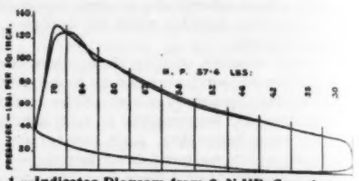


Fig. 1.—Indicator Diagram from 9 N.HP. Crossley "Otto" Engine, No. 8,705, 1888.

Diameter of cylinder, 9 ins.; stroke, 18 ins.; revs. per min., 160; 15.05 I. HP. at 58.4 lbs. mean pressure (average of three cards); gas consumption per I. HP. per hour, 23.98 cu. ft.; (Birmingham gas, 17 c. p.); B. HP., 13.37; gas consumption per B. HP. per hour, 27 cu. ft.; maximum pressure of explosion, 133 lbs. per sq. in.; pressure of compression, 38 lbs. per sq. in.; compression space, 0.6 of volume swept by piston.

The heat evolved per cubic foot of gas varies with the composition of the gas in different towns; so that an engine might consume more gas in one town than another, and yet be converting quite as large a fraction of heat into mechanical work. To enable this to be calculated, the Author gives, in Table I herewith, analyses by Dr. Percy F. Frankland of coal gas as supplied in nineteen of the principal towns in Great Britain, and from those particulars he has calculated the various data required in gas-engine calculations. From this table it will be found that Glasgow gas, in 1882, evolved heat equivalent to 588,530 ft.-lbs. per cu. ft. measured at atmospheric pressure (14.7 lbs. per sq. in.) and 62°.6 F. temperature. From another column it will be found that if all this heat could be converted into mechanical work it would only require 3.3643 cu. ft. of the gas to indicate one HP. for an hour. The indicated efficiency, E, of an engine consuming 22 cu. ft. per I.HP. hour is therefore—

$$E = \frac{3.3643}{22} = 0.152.$$

Calculating the London and Birmingham tests in the same manner, gives E = 0.167, and E = 0.17 respectively.

The earlier experiments of Dr. Slaby[1] and Prof. Thurston[2] gave respectively 0.16 and 0.17 as the indicated efficiency of engines not greatly differing in dimensions. It may be considered, then, that up to the end of 1887, the best efficiency of Otto engines of between 5 I.HP. and 15 I.HP. was as nearly as possible 0.17; that 0.17 of the heat of the gas appeared on the diagram as indicated work. Both the experimenters referred to have erroneously calculated the heating value of the gases used by excluding the heat of evaporation of the water formed. Correcting their results for this, the efficiencies become respectively 0.14 and 0.15. The compression used up to this time did not exceed 40 lbs. per sq. in. above atmospheric pressure.

*A paper read before the Institution of Civil Engineers.

[1] Minutes of Proceedings Inst. C. E., Vol. LXIX., p. 220.

[1] Minutes of Proceedings Inst. C. E., Vol. LXIX., p. 227. See also "The Gas Engine," by Dugald Clerk, London, Longmans, Green & Co., 1886, p. 53.

[2] "Experiments on the 'Otto' Gas Engine," Van Nostrand's "Engineering Magaline," Vol. XXX., 1884.

[1] Jenkin, "Gas and Caloric Engines," Appendix IV., Lectures Inst. C. E., Session 1883-84.

TABLE I.—COMPOSITION OF COAL AND CANNEL GASES FROM ANALYSES BY P. F. FRANKLAND, 1882-4[1], AND DATA CALCULATED THEREFROM.

Town.	Reputed illuminating power, c. p.	Hydro-carbons, C_n H_m.	Equivalent in ethylene, C_2 H_4.	Average formula of C_n H_m., Carbon density.	Hydrogen density.	Carbonic anhydride, CO_2.	Oxygen.	Nitrogen.	Hydrogen.	Carbonic oxide, CO.	Marsh gas, CH_4.	Ratio of illuminating power equivalent of C_2H_4 per cent. or 1 per cent. C_2H_4 = standard c. p.	Price per 1,000 cu. ft.	Weight of 100 cu. ft. at 14.7 lbs. per sq. in.	Volume of 1 lb. weight, at 14 lbs. per sq. in. pressure.	Heat evolved by 1 lb. weight, B. T. U.	Heat evolved by 1 cu. ft. at 14.7 lbs. per sq. in. pressure. At 32° F.		At 62°.6 F.		Volume at 62°.6 F. and 14.7 lbs. per sq. in. pressure, which evolves 1,000,000 ft.-lbs., or 1 HP. for 1 hr.
														32° F. lbs.	62°.6 F. lbs.	32° F. cu. ft.	62°.6 F. cu. ft.	B. T. U. ft.-lbs.	B. T. U. ft.-lbs.	
Edinburgh	30?	12.23	16.55	2.71	5.38	0.35	1.00	3.64	33.24	6.61	42.93	1.81	3s. 10d.	4.355	4.100	22.97	24.39	19,827	863	666,560	813	627,740	3.154
Glasgow	27	10.00	13.40	2.68	5.09	0.29	0.06	3.07	39.18	7.14	40.26	2.01	3s. 8d.	3.926	3.691	25.47	27.09	20,604	810	625,960	762	588,530	3.3643
St. Andrew's	27	10.04	13.71	2.73	5.09	2.73	0.48	2.83	36.63	5.16	42.13	1.97	4s. 2d.	4.182	3.937	23.91	25.40	19,690	820	633,030	772	595,890	3.322
Liverpool	21½	7.90	9.50	2.41	5.09	1.70	0.19	6.10	36.44	3.39	44.28	2.26	2s. 10d.	3.908	3.679	25.60	27.18	19,551	764	589,770	720	555,490	3.564
Preston	20	6.22	8.41	2.70	5.09	0.84	0.25	4.79	43.95	4.62	39.33	2.38	3s.	3.533	3.326	29.13	30.07	20,471	703	542,680	681	525,720	3.766
Nottingham	18½	5.63	8.24	2.93	5.09	0.81	0.24	2.51	45.52	5.63	39.66	2.25	2s. 6d. to 2s. 8d.	3.435	3.234	29.11	30.92	21,375	734	567,040	691	533,830	3.709
Leeds	18	7.28	10.64	2.92	5.09	0.34	0.07	4.32	40.23	5.02	42.74	1.69	1s. 10d.	3.932	3.702	25.43	27.01	18,786	739	570,490	695	537,110	3.686
Sheffield	18	6.28	8.78	2.79	5.09	0.24	0.10	2.56	43.05	4.72	43.05	2.05	2s. to 2s. 4d.	3.738	3.519	26.76	28.42	20,520	767	592,150	830	557,570	3.551
Birmingham	17¾	4.76	6.28	2.64	4.29	1.50	0.36	10.10	40.23	4.05	39.00	2.75	2s. 3d. to 2s. 9d.	3.793	3.571	26.37	28.00	17,645	669	516,730	630	486,650	4.069
Bristol	17	4.58	7.77	3.39	4.29	1.50	0.27	5.11	44.57	4.77	40.70	2.19	2s. 8d. to 2s. 10d.	3.485	3.281	28.69	30.48	20,945	732	563,750	687	530,640	3.713
London:																							
Gas‡ & Coke Co.	16	4.41	6.58	2.98	4.32	1.50	0.26	5.95	47.90	3.75	37.64	2.43	3s. 2d.	3.332	3.137	30.01	31.88	20,666	688	531,770	648	500,580	3.955
So. Metropol. Co.	16	2.92	4.42	3.03	5.16	0.09	0.26	3.19	53.14	4.11	36.55	3.62	2s. 10d.	2.866	2.700	34.89	37.04	22,912	664	507,110	618	477,680	4.145
Redhill	16	4.40	5.91	2.69	4.58	0.74	0.49	3.37	48.18	3.41	39.41	2.71	4s. 6d. to 5s.	3.160	2.975	31.65	33.61	21,906	692	534,480	652	503,320	3.934
Gloucester	16?	4.95	7.10	2.87	4.58	0.03	0.51	2.73	48.89	4.64	38.25	2.25	.....	3.172	2.986	31.54	33.49	22,282	707	545,560	665	513,790	3.853
Newcastle-on-Tyne	16	3.62	5.00	2.76	4.58	0.28	0.23	5.29	50.50	3.37	36.71	3.20	1s. 10½d.	3.053	2.874	32.75	34.79	21,494	656	506,810	618	477,090	4.156
Brighton	14	3.76	4.60	2.45	4.62	0.03	0.23	2.07	51.62	4.14	38.15	3.04	3s. 3d. to 5s. 3d.	2.862	2.694	34.94	37.12	23,432	670	517,890	631	487,480	4.062
Southampton	14	3.09	4.90	3.17	5.20	0.07	0.39	2.53	53.59	3.59	36.74	2.86	3s. 2d. to 3s. 8d.	2.852	2.431	35.06	41.13	23,369	666	514,730	568	438,760	4.153
Newcastle (Lyme)	15	4.53	5.67	2.47	4.58	0.08	0.11	6.22	46.31	3.74	39.01	2.65	3s. 6d.	3.151	2.966	31.74	33.71	21,548	679	524,250	630	493,310	4.011
Ipswich	14	4.53	5.82	2.57	3.77	0.06	0.12	10.84	43.26	2.46	38.73	2.40	3s. 6d.	3.500	3.294	28.57	30.36	18,963	665	513,530	572	483,250	4.097
Norwich	14?	3.26	4.85	2.97	3.40	0.27	0.14	3.03	59.79	3.40	36.11	2.89	2s. 6d. to 2s. 8d.	2.880	2.711	34.72	36.89	23,782	685	528,940	645	497,820	3.977

[1] "The Composition and Illuminating Power of Coal Gas." By Percy Frankland, Ph. D. A paper read May 5, 1884, before the London section of the Society of Chemical Industry, "Journal of Gas Lighting," July 1, 1884, p. 17.

TABLE II.—Particulars of a 6 N. HP. Crossley "Otto" Gas-Engine (No. 4,683) Built about 1881, and of a 9 N. HP. Crossley "Otto" Gas-Engine (No. 19,772) Built in 1892.

	6 N. HP. Engine, No. 4,683.	9 N. HP. Engine, No. 19,772.
Diameter of cylinder, ins.	8	9½
Length of stroke, ins.	16	18
Volume swept by piston, cu. ins.	804	1,275.8
Volume of compression space, cu. ins.	516	510
Volume of compression space ÷ volume swept by piston	0.64	0.4
Pressure of compression above atmosphere, lbs. per sq.in.	31	48
Max. pressure of explosion above atmos., lbs. per sq. in.	126	200
Mean available pressure, lbs. per sq. in.	57	81.5
Revolutions per minute	164	160
I. HP.	9.0	19.25
B. HP.	6.75	15.75
Gas consumption, per hour, cu. ft.	230	408
Gas per I. HP. per hour, cu. ft.	25.5	21.2
Gas per B. HP. per hour, cu. ft.	34	25.9
Theoretical efficiency of an air-engine	0.32	0.40
Actual indicated efficiency	0.159	0.175
Mechanical efficiency	0.75	0.82
Area of charge inlet port	Slide-valve, 1.5 sq. in.	2⅜ ins. diam. × ⅞-in. lift, 4.43 sq. ins.
Inlet port setting	To ¼-in. open when piston is on center and still opn ⅛in.on outer center	Opens dead on in center; is held open on out center, closes pist. retrns 1½ ins.
Exhaust valve	2¼ ins. diam. × ⅜-in. lift, 2.65 sq. ins.	3 ins. diam. × 1¼-in. lift, 7.06 sq. ins.
Exhaust-valve setting	Valve opens when piston is still 1-in. from out end of stroke, closes when piston has crossed in cntr; movd ½-in. out	Valve opens when piston is still 2¼ ins. from out end strke; closes on in cent'r.
Ignition-valve setting.	Ignition port ⅛-in. open when crank is on in center. (Slide.)	Valve 5-16-in. diam. × 5-16-in. lift; opens 1½-in.strke before compres'n is complete,full op'n ½-in.before compression is complete.*
Charge velocity, ft. per sec.	244	128
Exhaust velocity, ft. per sec.	137	81
Piston speed, ft. per min.	437	480
Power absorbed charging and exhausting, I. HP.	0.65	0.64
Gas inlet-valve	⅜-in. diam. × ⅜-in. lift.	1-in. diam. × ⅜-in. lift.
Gas inlet-valve setting	When piston has made 1¼-in. forward stroke, valve opens.	When piston has made 2½-in. forward stroke the valve opens, and closes when piston has returned 1¼-in.

*Tube ignition.

At the end of 1888, an important series of tests was made by the Society of Arts; Dr. John Hopkinson, Dr. Kennedy, and Mr. Beauchamp Tower acting as judges for the Society. The trials were intended to compare the relative merits of various motors for electric lighting, three gas-engines and one steam-engine being entered for trial. All the gas-engines were worked in accordance with the Otto cycle. The engine submitted by Messrs. Crossley had a cylinder 9½ ins. in diameter, with a stroke of 18 ins. The consumption of gas at full load was found to be 20.55 cu. ft. per I.HP. hour, and the compression was 61.6 lbs. per sq. in. above atmospheric pressure, and volume of compression space 0.4 of that swept by piston. The indicated HP. was 17.12, and the brake HP. 14.74 at a speed of 160.1 revolutions per minute; the gas consumed per brake HP. hour was 23.87 cu. ft., or, allowing for igniting flame, 24.10 cu. ft. The mean effective pressure was 67.9 lbs. per sq. in.; and the mean initial pressure of the explosion was 196.9 lbs. The heating value of the gas used was found by analyses to be 483,270 ft.-lbs. per cu. ft., the gas being measured at 32° F., and 14.7 lbs. per sq. in. atmospheric pressure. The temperature of the gas in the meter was 64°.4 F., and the barometric pressure 14.9 lbs. per sq. in., so that 4.308 cu. ft. would be required to furnish heat-units equivalent to one HP. for an hour. The absolute efficiency was therefore—

$$E = \frac{4.308}{20.55} = 0.21.$$

Thus, at the end of 1888, the best result obtained from a Crossley Otto engine was, according to the Society of Arts experiments, the conversion of 21% of the heat supplied to the engine into indicated work appearing on the diagram; a creditable advance on the consumption of the Otto engine in 1882. In the Author's opinion, however, an erroneous basis of calculation for the determination of the heating value of coal-gas was adopted. In the heating value of the gas was included only heat evolved by cooling the products to 212° F. The whole heat of combustion from the temperature before ignition down to the same temperature should be taken in any estimation of the absolute heat efficiency of an engine. Amending the Society of Arts calculation for this, 3.88 cu. ft. of gas would give sufficient heat, if all were converted into work, to give 1 HP. for an hour, so that the absolute efficiency would be $\frac{3.88}{20.55} = 18.9\%$ instead of 21%.

From 1888, until 1894, the latter figure remained as the best Otto engine consumption; but in the latter year Messrs. Crossley, in conjunction with Mr. James Atkinson, succeeded in obtaining considerably greater economy. Messrs. Crossley Bros. placed one of their new type of 4-HP. (nominal) engines at the Author's disposal for the purposes of a test, in order to verify the extraordinarily low consumption obtained. Accordingly he made a very careful test at Openshaw on Aug. 31, 1894. Fig. 2 is a diagram taken from that engine.

Taking the heating value of Openshaw gas as 530,000 ft.-lbs. per cu. ft. at 62°.6 F., and 14.7 lbs. pressure per sq. in., 3,736 cu. ft. would supply heat enough, if all converted into work, to perform 1 HP. for an hour. As the consumption per I.HP. hour is 14.8 cu. ft. it follows that the absolute indicated efficiency is.

$$E = \frac{3.736}{14.8} = 0.25;$$

that is, the engine converts 25% of all the heat given to it into indicated work. This is an extraordinary good result, and as it was much lower than any gas consumption the Author had ever noted before, he had every necessary test made of the meter, the brake weight and the indicator, in order to make certain of substantial accuracy. This engine, although possessing only a 7-in. cylinder with a 15-in. stroke, gave practically 12 brake HP. with a gas consumption of only 17 cu. ft. of gas per brake HP. hour, a surprisingly good result for so small an engine. With a larger engine better results are obtained; with an engine of 14 nominal HP., having an 11½-in. cylinder diameter and 21-in. stroke, Mr. J. Atkinson obtained, also at Openshaw, an average available pressure of 100 lbs. per sq. in., 46.8 indicated HP., and a gas consumption of 13.55 cu. ft. per I.HP. hour. This gives an absolute indicated efficiency of

$$E = \frac{3.736}{13.55} = 0.275.$$

Substantial improvement has therefore been made by Messrs. Crossley in the economy of gas since 1882, and it is interesting to note that each step of diminished gas-consumption is attended by an increase in compression; this is evident from the Table below. The experiments (1) and (2) were made with engines having cylinders 9 ins. and 9½ ins. in diameter respectively, both engines having an 18-in. stroke; so that they may be considered to be of the same dimensions so far as change of economy due to change of dimensions is concerned. The result (3) was obtained with an engine having a cylinder of 7 ins. diameter and 15 ins. stroke, so that 0.26 would more properly represent the efficiency to be obtained from an engine of the same dimensions as in the other experiments:

Absolute Indicated Efficiency of Crossley "Otto" Engines of Similar Size Since 1882.

	Efficiency.	Pressure of Compression above Atmosphere. Lbs. per sq. in.
1. 1882-88	0.16	58.0
2. 1888-94	0.19	66.6
3. 1894	0.25	87.5

From these results it is evident that economy increases with compression. But it is open to question whether the increased compression completely accounts for the improved performance. If the calculated result from the various compression pressures accounts for the whole change of gas consumption accompanying change of pressure, then it is evident that the improved economy is to be credited to the increase of compression only. To test this, the Author has calculated, by formula (ii), the theoretical efficiency of an air engine in which no practical losses occurred, the air-engine having the same ratios of compression space as the actual gas-engines. These theoretical efficiencies are shown in the appended Table placed beside the actual efficiencies obtained in the gas-engine.

From this Table it is evident that the improved economy is chiefly accounted for by the increased compression. In every case the actual indicated efficiency obtained from the various gas-engines ranges from a little under to a little over half of that which would be given by an ideal air-engine following the same cycle in a perfect manner without loss of heat to the sides of the cylinder.

The actual efficiency improves somewhat more rapidly with the increase of compression than does the thermodynamic advantage due to compression. That is, when the theoretical efficiency is 0.33, the actual experimental efficiency is $0.33 \times 0.45 = 0.15$, with theoretical efficiency 0.39 the actual efficiency is $0.39 \times 0.48 = 0.19$, while with 0.428 theoretical, the actual efficiency is $0.428 \times 0.58 = 0.25$.

The ratio of actual to ideal efficiency thus rises from 0.45 to 0.58. This means that with higher compressions, in addition to the thermodynamic advantage due to change of cycle, there is also a further advantage due to a diminution of the proportional loss of heat to the cylinder walls.

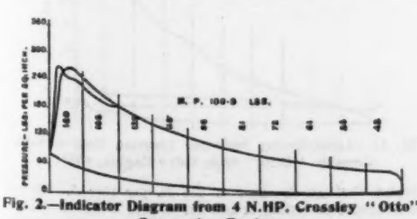


Fig. 2.—Indicator Diagram from 4 N.HP. Crossley "Otto" Scavenging Engine.

Diameter of cylinder, 7 ins.; stroke, 15 ins.; revs, per min., 200; I. HP., 14 at 100 lbs. per sq. in. mean pressure (average of three cards); gas consumption per I. HP. per hour, 14.8 cu. ft. (Openshaw gas, 20 c. p.); B. HP., 11.97; gas consumption per B. HP., per hour, 17 cu. ft.; maximum pressure of explosion, 275 lbs. per sq. in; pressure of compression, 87.5 lbs. per sq. in.; compression space, 34% of volume swept by piston.

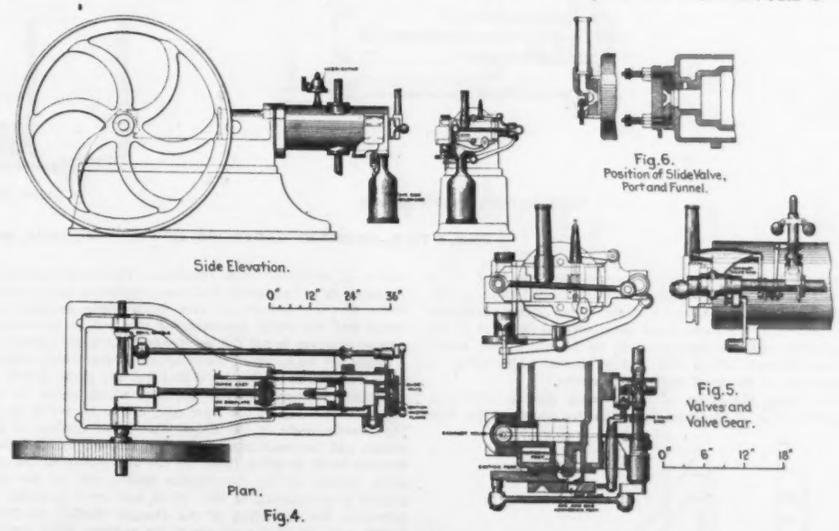


Fig.4.

FIGS. 4 TO 6.—CROSSLEY GAS ENGINE OF 6 H.P., NO. 4683, BUILT IN 1882.

Table Showing Theoretical Indicated Efficiency of Crossley "Otto" Engines with Different Compressions, Compared with Actual Indicated Efficiencies with the Same Compressions.

E = calculated efficiency for perfect "Otto" Cycle Engine from compression space volume.	E = actual indicated efficiency from diagram and gas consumption.	Ratio of actual to ideal efficiency.	Cylinder diameter. ins.	Piston stroke. ins.	Ratio of compression space to space swept by piston.	Pressure of compression. lbs.	Gas consumption per I. H.P. per hour. cu. ft.
0.33	0.15	$\frac{0.15}{0.33} = 0.45$	9	18	0.6	38.0	24.0
0.4	0.189	$\frac{0.189}{0.40} = 0.47$	9½	18	0.4[2]	61.6	20.5
0.39[1]	0.19	$\frac{0.19}{0.393} = 0.48$	8½	18	0.418	53.0	20.3
0.428	0.25	$\frac{0.25}{0.428} = 0.58$	7	15	0.34	87.5	14.8

[1]Test by Prof. Capper; "A Text-book on Gas, Oil and Air-Engines," by Bryan Donkin, M. Inst. C. E., Appendix, Section A, p. 355.
[2]This value is given by the Society of Arts, but it appears wrong.

In the last experiment (3) part of the economy is probably due to the displacement of the exhaust products by pure air.

It follows that probably further economies are to be obtained by increase of compression, care being taken to preserve a properly shaped compression space, i. e., a space having small cooling surfaces in relation to the volume of the compressed charge. Some of the advantage is also due to the more rapid conversion of the heat of the explosion into mechanical work, by reason of the small space through which the piston moves while doing a large part of the total work of its stroke.

To render the effect of compression readily visible, a diagram, Fig. 3, is given, in which the length of the line

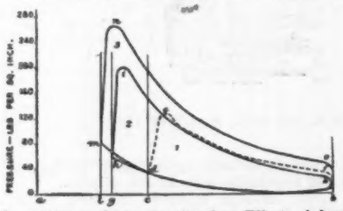


Fig. 3.—Indicator Diagram showing Effect of Increased Compression.

a b represents the total capacity of the cylinder including the compression space; c b represents the stroke, and a c the compression space according to the diagram d e f b. The line a g represents the compression space, and g b the stroke of the "Otto" engine tested by the Society of Arts, while h i k b is the diagram given in the Society of Arts Report plotted to the same scale as the first diagram. The line a l represents the compression space, and l b the stroke of the engine tested by the Author at Messrs. Crossley's works, while m n o b is the diagram 3. It is evident that No. 2 is larger in area than No. 1, and that No. 3 is considerably larger than both. The diagrams, Nos. 1 and 2, were taken with precisely the same amount of gas present in the cylinder per cubic foot of space; but in the case of No. 3 the amount of gas present was greater, so that to truly represent the respective economies obtained by the three compressions, the diagram No. 3 should be diminished.

The increased heat efficiency of the Crossley "Otto" cycle engine is then clearly in the main due to increased compression; it is now advisable to consider the mechanical changes which have accompanied and rendered possible these economies.

Comparison of a Crossley Otto Gas-Engine built in 1882, and one built in 1892.—Figs. 4 to 6, show details of a Crossley Otto engine, No. 4683, of 6 HP. nominal, built about 1882 and now at work in Birmingham. Figs. 7 to 9 illustrate a recent engine, No. 19,772, of 9 HP. nominal, by the same makers, now at work at the Clifton Rocks Railway, Bristol. Fig. 5 shows the valve and lever arrangements; and a section showing the position of the slide-valve port and funnel is given in Fig. 6.

A comparison of the illustrations shows at once that the later engine is a great improvement upon the earlier in design. From a constructive point of view the earlier type had several inconvenient features which have been removed; thus, the cylinder in the earlier type of engine had to be adjusted accurately concentric with the guide forming part of the engine frame; this difficulty has been overcome by making the cylinder serve both as cylinder and slide-guide; the whole being bolted to the bed against a strong faced flange, and this permitting of the ready removal of the liner when required. The bevel-wheels are replaced by skew-wheels, and this provides a much quieter drive for the two-to-one cam-shaft, while avoiding the somewhat unsightly distortion of the bed of the earlier engine in order to get the bevel-wheels properly applied.

There are many small constructive details which experience has shown to be desirable; but the great points of departure between the two engines, which result in the superior economy of the later one, are to be found in (a) the abandonment of the flame slide-valve method of ignition, and the substitution for it of ignition by an incandescent metal or other tube; (b) the diminution in the relative volume of the compression space; and (c) the improved proportioning of the valves and ports in order to minimise the throttling of the charges during the inlet period, and the back pressure of the exhause gases during discharge.

In the slide-valve Otto engine, Figs. 4 to 6, the port in the back cover is 2⅝ ins. by ⅝ in., or 1½ sq. ins. in area, and a maximum pressure of 150 lbs. per sq. in. is often attained in this engine. This means that the slide-valve has to be held to its cover by a pressure exceeding 225 lbs.—as a matter of fact, the pressure of the springs on this slide exceeds 600 lbs. When it is considered that the flame temperature of the contents of the cylinder and port is about 2,912° F., it is easy to see how great is the difficulty of keeping the slide in working order, even at the lower compressions.

The slide-valve in these engines undoubtedly presented a formidable difficulty, and so long as it remained essential, prevented the successful use of higher compression and flame pressures. Messrs. Crossley appear to have abandoned the slide-valve for the first time in the engine built for the Society of Arts trials, and then applied the incandescent-tube igniter. The igniter used by them until recently is shown in section at Figs. 8 and 9. This form of igniter appears to have been proposed for the first time by the late Sir C. W. Siemens, but it was not successfully applied until re-introduced by Mr. J. Atkinson about 1880. In Great Britain the tube igniter

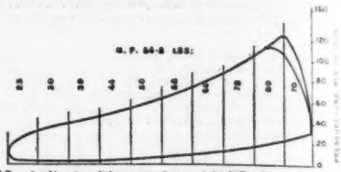


Fig. 10.—Indicator Diagram from 6 N.HP Crossley "Otto" Slide-Valve Engine, 1881.

Diameter of cylinder, 8 ins.; stroke, 16 ins.; revs. per min., 164; I. HP. at 57 lbs. mean pressure (average of four cards), 9; gas consumption per I. HP., per hour, 25.5 cu. ft. (Birmingham gas); B. HP., 6.75; consumption per B. HP., per hour, 34 cu. ft.; maximum pressure of explosion, 126 lbs. per sq. in.; pressure of compression, 31 lbs. per sq. in.; compression space, 0.64 of the volume swept by the piston.

has now displaced all other forms of igniting gear. It allows the compression to be increased to any desired extent, without giving rise to practical difficulties. The higher compression which is made practicable by this igniter is the main distinguishing feature between the early and the recent Crossley Otto engines illustrated.

Another important difference also follows from the abandonment of the slide-valve. In the older engines the limitation of the admission area through the slide was important, and so the entering air and gas charge was somewhat throttled. A test was made of the slide-valve engine, Figs. 4 to 6, by the Author in September, 1894, from which he obtained the diagram, Fig. 10. With this engine, assuming the port to be fully open during the whole forward stroke, and taking the average piston-speed as 437 ft. per minute, there is given with a cylinder area of 50.26 sq. in., an average velocity of the air and gas mixture

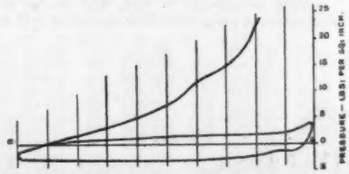
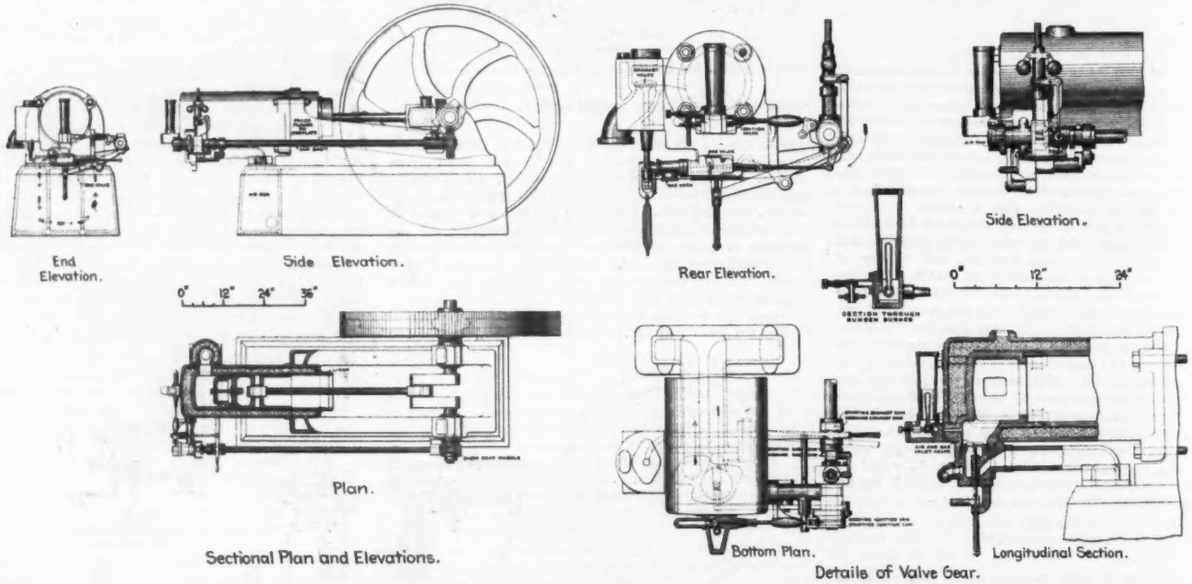
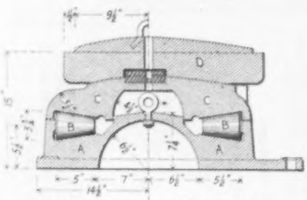


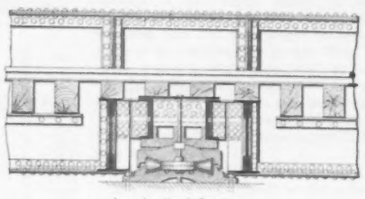
Fig. 11.—Light-Spring Indicator Diagram from 6 N.HP. Crossley "Otto," Slide-Valve Engine, 1881.

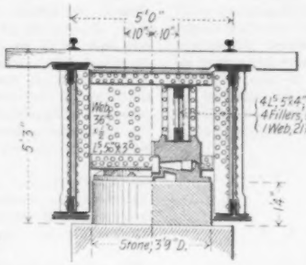
flowing through the port of 244 ft. per second. Hence considerable throttling is caused, so that when the piston attains its complete out stroke, the pressure in the cylinder is below that of the atmosphere. To allow the cylinder to fill as much as possible, the admission port in the slide was set to remain open until the crank had crossed the out center and the piston had just begun its instroke. Notwithstanding this, the pressure in the cylinder at the outer



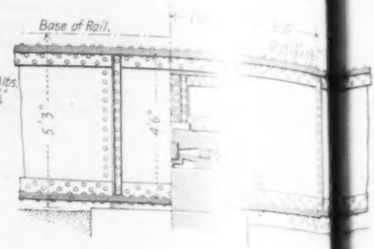
FIGS. 7 TO 9.—CROSSLEY GAS ENGINE OF 9 H.P., NO. 19772, BUILT IN 1892.







Transverse Section at Center.



Sectional Side E

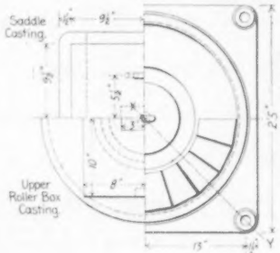


Fig. 3. Details of Center Pivot.

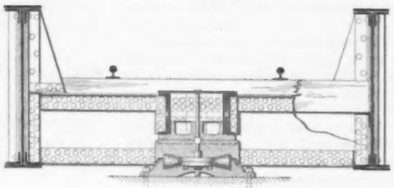
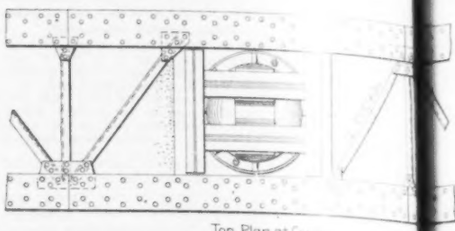


Fig. 2. Center Girder Construction—Half Through Tables.

Fig. 1. Center Girder and Pivot Construction.



Top Plan at Ce

MINNEAPOLIS, ST. PAUL & SAULT STE. MARIE RY. CO.'S TAN

Detroit Bridge and Iron Works, Detroit, Mich

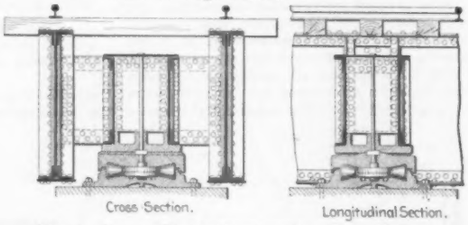
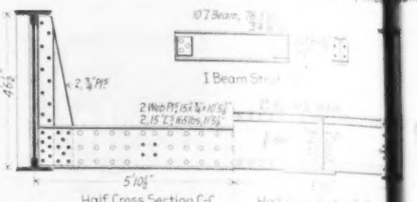
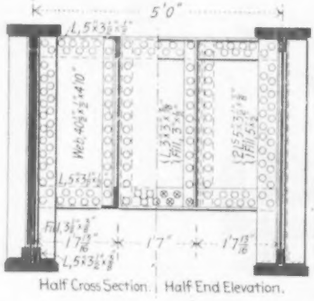


Fig. 1. Center Girder Construction—Deck Tables.

PHILADELPHIA BRIDGE AND IRON WORKS (COFRODE & SAYLOR) STANDARD TURNTABLES.





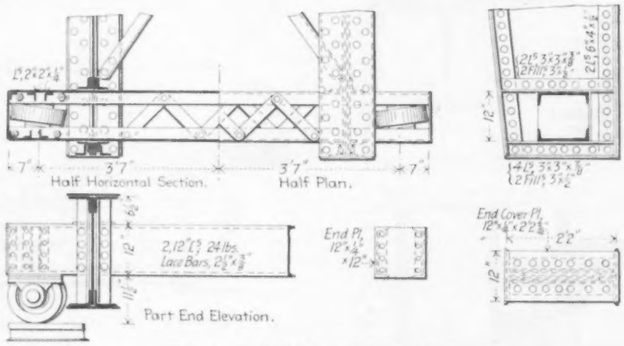


Fig. 3. End Girder and Roller Construction.

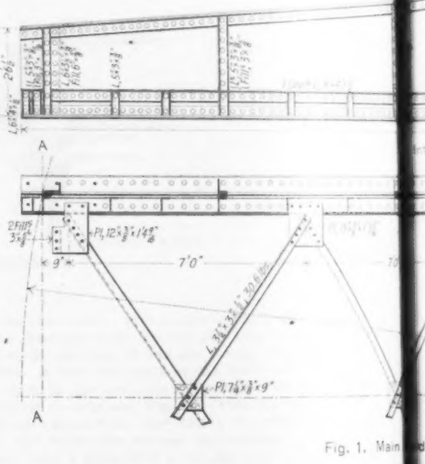
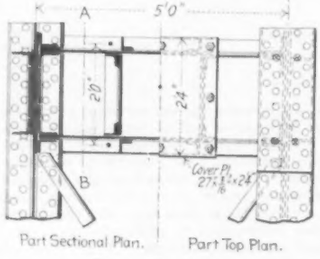


Fig. 1, Main



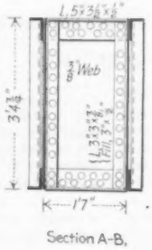


Fig. 1. Center Girder Construction.

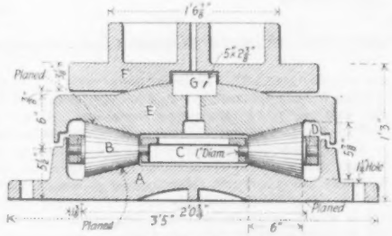


Fig. 2. Details of Center Pivot.

LAKE SHORE
& MICHIGAN SOUTHERN RY. CO.'S
STANDARD TURNTABLE.

King Bridge Co., Cleveland, O.,
Builders.

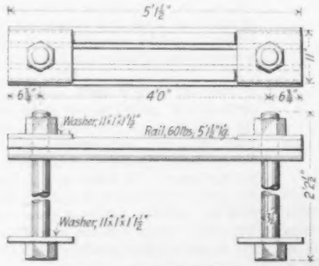


Fig. 3. Adjusting Frame at Center.

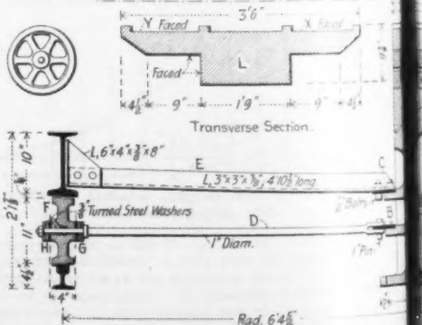
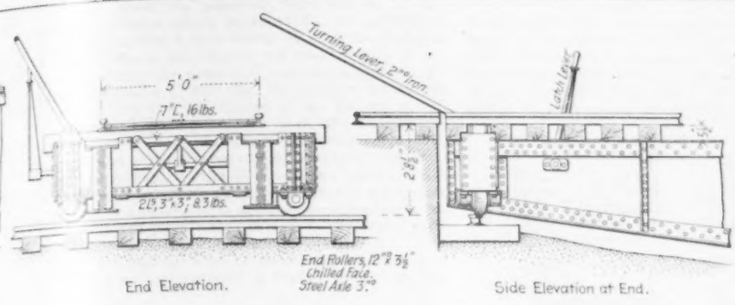


Fig. 2. Details of Center Pivot

NEW YORK CENTRAL & HUDSON RIVER R. R. CO.'S SPECIAL T

RECENT EXAMPLES OF RAILW



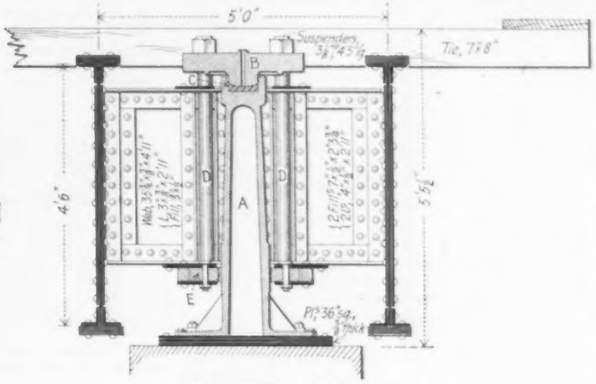


Fig. 1. Details of Center Pivot.

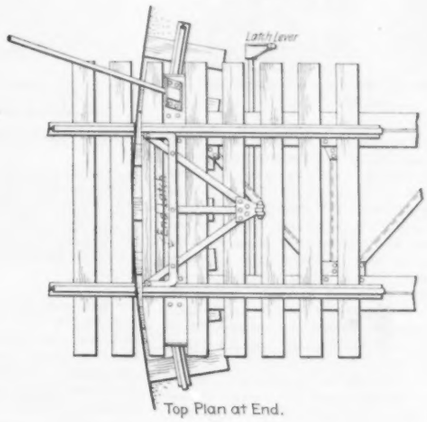
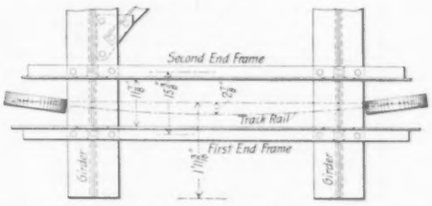


Fig. 2. End Girder and Roller Construction.



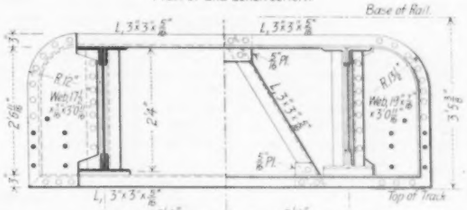
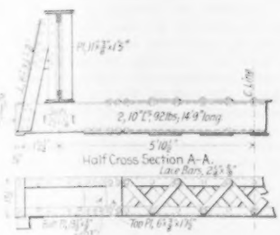
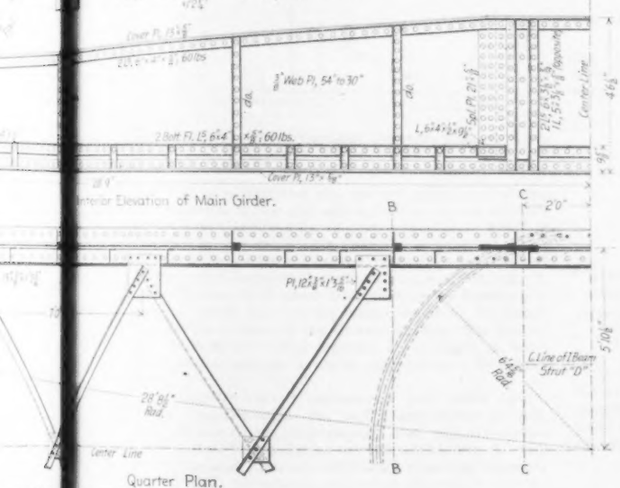
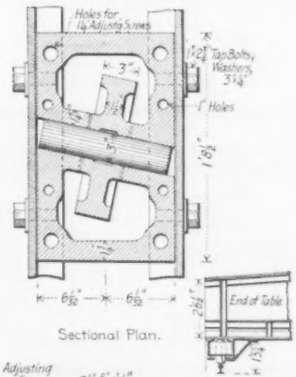


Fig. 3. End Girder and Roller Construction.

E RY. CO.'S TANDARD TURNTABLE.
Detroit, Mich., Builders.







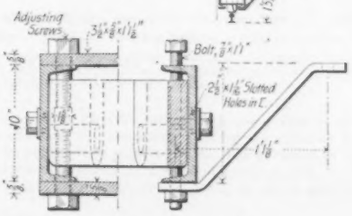


Fig. 5. Details of Trailing Wheels.

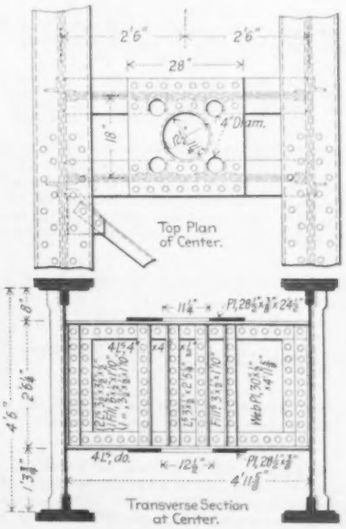
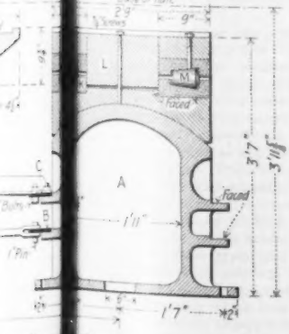


Fig. 2. Center Girder Construction.

LEHIGH VALLEY R. R. CO.'S 60-FT. TURNTABLE.

Union Bridge Co., New York, Builders.

. 1. Main ...der and Floor Construction.



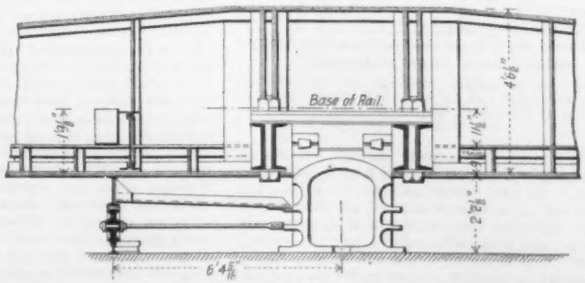


Fig. 4. General Arrangement of Center Bearing.

...nter Pivot ... Drum.

...PECIAL T...OUGH TURNTABLE. Elmira Bridge Co., Elmira, N. Y., Builders.

RAILWA... TURNTABLE CONSTRUCTION.

end of the stroke was somewhat below that of the atmosphere. This is clearly shown in Fig. 11, which is a diagram taken with a light spring, to show the charging stroke. It will be seen that at the outer end (6) of the charging stroke, the point c is considerably below the atmosphere line a b, and that the pressure within the cylinder is only 13.0 lbs., instead of 14.7 lbs. per sq. in. This seriously reduces the charge taken into the cylinder, and so makes the mean available pressure much less. The available area of the exhaust opening is only 2.65. sq. ins., so that the average velocity of the exhaust gases is 137.3 ft. per second, which is quite reasonable for hot gases; but it is such a velocity as to cause undue resistance to the discharge of cold gases, and as cold air is discharged while the engine is governing it is desirable to reduce it.

Fig. 12 is a diagram taken by the Author in a recent test of the Otto engine illustrated in Figs. 7 and 9. In this

Fig. 12.—Indicator Diagram from 9 N.HP. Crossley "Otto" Engine, 1892.

Diameter of cylinder, 9½ ins.; stroke, 18 ins.; revs. per min., 160; I. HP., 19.25 at 81.5 lbs. mean pressure (average of four cards); gas consumption per I. HP. per hour, 21.19 cu. ft. (Clifton gas); B. HP., 15.75; consumption per B. HP. per hour, 25.9 cu. ft.; maximum pressure of explosion, 200 lbs. per sq. in.; pressure of compression, 48 lbs. per sq. in.; compression space, 0.4 of piston displacement.

ngine the piston speed was 480 ft. per minute, and the area of the cylinder was 70.88 sq. ins. The suction area of the inlet gas and air-valve when fully open was 4.43 sq. ins., and the velocity of the entering charge was 128 ft. per second, assuming the valve fully open during the whole stroke. The maximum area of exhaust discharge was 7.06 sq. ins., so that the speed of exhaust discharge was 81 ft. per second, assuming the valve to be full open during the whole exhaust stroke. The light-spring diagram, Fig. 13, shows the great improvement effected by so diminishing the resistance to the inlet and the discharge.

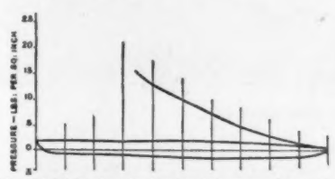


Fig. 13.—Light-Spring Indicator Diagram from 9 N.HP. Crossley "Otto," 1892.

It is to be remembered that the evil effect of throttling the admission of the gas and air charge is not confined to the power absorbed by the extra resistance, which is trifling. In this engine, for example, a reduction of 1½ lbs. per sq. in. below atmospheric pressure at the out end of the stroke means that the total volume of charge admitted is reduced by about 20%, because the reduction of pressure affects not only the volume swept by the piston, but also the volume of the clearance space. The leading data of these two "Otto" engines are arranged in Table II, in such a form as to enable comparison to be readily made.

The Crossley "Otto" engines now built differ considerably from the engine No. 19,772, constructed in 1892; they are now of the "scavenging" type, and are similar to that tested by the Author at their works, Fig. 2. This engine operated somewhat differently from that shown in Figs. 7 to 9. The general design, bed and details were the same, but an important improvement was made, which possessed an additional advantage in introducing no complications.

The Author has long contended that no advantage has ever been gained in the "Otto" or any other gas engine, by retaining the products of combustion in the compression space. These products are better discharged and the space filled with combustible mixture or pure air, if it can be effected without mechanical complications. Many of the Author's experiments were conducted specially with that end in view, as applied to engines with an impulse at every revolution. From being among the most prominent holders of what may be called the "combustion products" theory of the cause of economy in gas-engines, Messrs. Crossley have entirely adopted the Author's view of the causes of economy in the modern gas engine; and their new invention offers proof that considerable advantages are to be obtained by clearing out the whole of the burned gases. It has been long known that if a puff of steam or gas be discharged into a long pipe, after a certain time the wave of pressure is succeeded by a fall of pressure, or partial vacuum. Messrs. Crossley and Atkinson take advantage of this, and control the wave and the following vacuum in such a manner that, after the exhaust gases have been liberated from the cylinder, the high-pressure discharge is succeeded by a vacuum; and they so proportion the length of the exhaust pipe that the vacuum period in the pipe coincides with the piston nearing the end of its stroke. By keeping open the exhaust valve, and opening the charge or air inlet-valve while the exhaust valve is open, a charge of pure air, or air and gas if need be is drawn

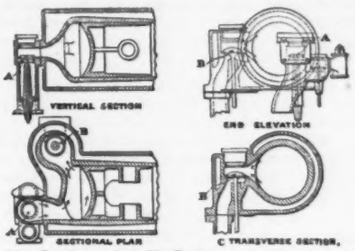


Fig. 14.—Sections of 4 N.HP. Crossley Otto Scavenging Engine.

through the combustion space of the engine; and all the products of combustion which would otherwise remain there are swept out from the compression space. When the charging stroke is complete, the cylinder is thus filled with a pure mixture of air and gas without the deleterious burned gases. To accomplish this sweeping-out in a satisfactory manner, it is necessary to shape the cylinder so as to favor a clean sweep by entering air. Fig. 14 illustrates the arrangement of the 4-HP. nominal engine tested by the author. Fig. 15 illustrates diagramatically the settings of the valves in that engine. The desired delay in the production of suction or vacuum is caused by attaching an exhaust pipe (C) about 65 ft. long to the exhaust passage. Quieting chambers may be placed at that length of the pipe without ill effect; but the pipe must be arranged without any large expension or chamber for about that length. It may be bent as much as is necessary to get in the requisite length. The energy of discharge of the exhaust sets the long column filling this pipe in mo-

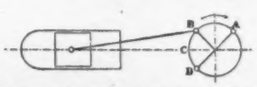


Fig. 15.—Diagram Illustrating Setting of Engine Valves.

tion, and produces a considerable reduction of pressure within the cylinder, notwithstanding the opening of the air-valve.

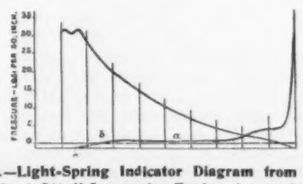


Fig. 16.—Light-Spring Indicator Diagram from 4 N.HP. Crossley "Otto" Scavenging Engine, August 31, 1894.

Showing how the exhaust-line a strikes the atmospheric-line b and falls below it to c, so causing suction through the cylinder to displace the exhaust.

The light-spring diagram taken from the engine during the Author's test, Fig. 16, shows plainly the effect of the vacuum so produced in exhaust pipe. The pressure is reduced within the cylinder to 2 lbs. below atmosphere, quite enough to cause a strong current of air to sweep through

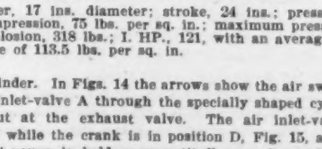


Fig. 17.—Indicator Diagram from 30 N.HP. Crossley "Otto" Scavenging Engine, Using Coal-Gas.

Cylinder, 17 ins. diameter; stroke, 24 ins.; pressure of compression, 75 lbs. per sq. in.; maximum pressure of explosion, 318 lbs.; I. HP., 121, with an average pressure of 113.5 lbs. per sq. in.

the cylinder. In Figs. 14 the arrows show the air sweeping in by inlet-valve A through the specially shaped cylinder, and out at the exhaust valve. The air inlet-valve is opened while the crank is in position D, Fig. 15, and the exhaust-vauve is held open until the crank reaches the position B. The exhaust-valve opens again at A, and it is held open to B instead of as usual to C. The method has been applied by Messrs. Crossley to engines of more than 100 I.HP.; Fig. 17 is a diagram taken from a 30-HP. nominal engine, giving with coal-gas 121 I.HP., on an average available pressure of 113.5 lbs. per sq. in. The compression shown is 75 lbs. per sq. in.

A diagram taken from the same engine, with Dowson gas, is shown in Fig. 18, from which it will be observed

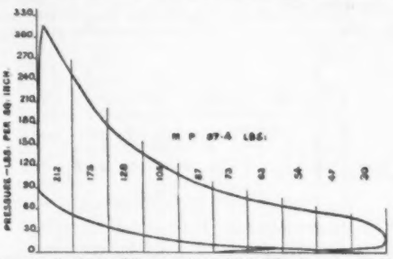


Fig. 18.—Indicator Diagram from 30 N.HP. Crossley "Otto Scavenging Engine, Using Dowson Gas.

Cylinder, 17 ins. diameter; stroke, 24 ins.; card from same engine as in Fig. 17

that the very satisfactory average pressure of 97.4 lbs per sq. in. was attained.

Mr. J. Atkinson, in a Paper[1] read before the Manchester Association of Engineers, attributes the whole of the economy he has obtained to the discharge of the exhaust gases and their replacement by pure air, and he entirely omits to note the effect of the increased compression which is used in conjunction with the scavenging air. The Author has always advocated "scavenging" a cylinder by means of air, and in many engines designed by him has entirely discharged the exhaust gases by air forced in by a pump. He has never been able, however, to credit such scavenging with more than 5% of economy, as compared with the same engine working at the same compression and retaining the exhaust gases. The results of many tests with gas-engines of the "three cycle" variety of Otto type, in which one revolution is devoted to replacing the whole of the exhaust gases by air, proves distinctly that the gas consumption per I.HP. at low compressions is not materially reduced by the act of displacing the exhaust products. Such engines have been constructed by Linford, Griffin, Barker and others before the expiry of the Otto master patent, but they did not show a large economy due to pure charge. The Author is indebted to Mr. A. R. Bellamy of Reddish, for the diagrams, Figs. 19 and 21, taken by him from a Stockport

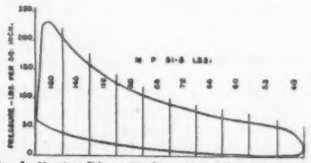


Fig. 19.—Indicator Diagram from 9 N.HP. Stockport "Otto" Engine, 60 lbs. per Sq. in. Compression; Engine No. 6,242.

Diameter of cylinder, 9¾ ins.; stroke, 17 ins.; revolutions per minute, 184; B. HP., 20.8; consumption per B. HP. per hour, 22.3 cu. ft.; maximum pressure of explosion, 244 lbs. per sq. in.

Otto cycle gas-engine having a cylinder of 9¾ ins. diameter by 17 ins. stroke.

The only difference between the two experiments is that in the first the compression space of the engine is proportioned to give a compression pressure of 60 lbs. per sq. in., while in the second one the compression is 90 lbs. per

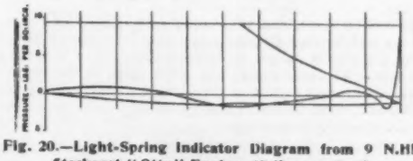


Fig. 20.—Light-Spring Indicator Diagram from 9 N.HP. Stockport "Otto" Engine, 60 lbs. per Sq. in. Compression; Engine No. 6,242.

sq. in. above the pressure of the atmosphere. The engine, when working with 60 lbs. per sq. in. compression, consumed 19 cu. ft. per I.HP. hour; while with 90 lbs. per sq. in. compression the consumption was reduced to 17.6 cu. ft. per I.HP. hour. The heat value of Reddish gas is about 500,000 ft.-lbs. per cu. ft., and so the efficiencies stand, with 60 lbs. per sq. in. compression, 0.208; with 90 lbs. per sq. in. compression, 0.225.

Figs. 20 and 22 are light-spring diagrams from the engines taken with the cards Figs. 19 and 21 respectively. The light-spring cards are practically the same, and show that no scavenging took place in the cylinder during either of the tests. It is therefore proved that in this experiment the improvement in economy is due to increase of compression only.

Scavenging by pure air, however, although not the sole cause of economy in the new engine, has great practical advantages, and, in the Author's opinion, it is absolutely

[1] "Engineering," Vol. lviii., p. 719.

essential to success with large gas-engines, especially when high compression is adopted. A great difficulty with large engines, and those using high compression, arises from liability to the premature explosion of the mixture

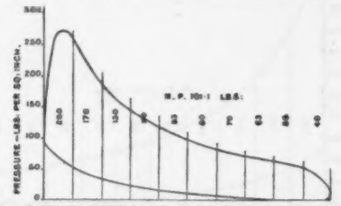


Fig. 21.—Indicator Diagram from 9 N.HP. Stockport "Otto" Engine, 90 lbs. per Sq. In. Compression; Engine No. 6,242.

Diameter of cylinder, 9¾ ins.; stroke, 17 ins.; revs., per min., 182; B. HP., 24.4; consumption per B. HP., per hour, 20.75 cu. ft.; maximum pressure of explosion, 272 lbs. per sq. in.

during the act of compression. This is largely caused by the presence of hot exhaust gases; and when these hot gases are removed by pure air, the cold pure mixture may be compressed to very high pressures without danger of early ignition. The admission of air in the first place also prevents any chance of the incoming charge being ignited during the charging stroke. The new method introduced by Messrs. Crossley & Atkinson is therefore most valuable,

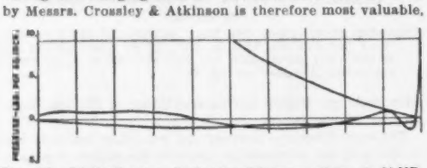


Fig. 22.—Light-Spring Indicator Diagram from 9 N.HP. Stockport "Otto" Engine, 90 lbs. per Sq. In. Compression; Engine No. 6,242.

permitting of working under conditions of maximum economy, and its very simplicity increases its value by avoiding the use of pumps or other mechanical air-supplying devices. It would occupy too much space to discuss the many ingenious details of the Crossley "Otto" engines of different sizes; the large engines of 250 I.HP. are, however, specially interesting.

(To be continued.)

THE PROPOSED MISSISSIPPI RIVER BRIDGE AT NEW ORLEANS.

This bridge, the plans for which are now complete in all their details, will cross the Mississippi River at 12-Mile Point, between four and five miles above the City of New Orleans. The Southern Bridge and Railway Company is chartered by Congress, and the bridge to be built by this company is to be operated as an independent enterprise for the benefit of all the railways centering at New Orleans and in the interest of the City of New Orleans.

The bridge itself will be a double-track structure, with the rails 100 ft. above the ground surface on either bank and offering a clear height in the river portion of 85 ft. above high water. This disposition requires an approach at each end 6,580 ft. long on a gradient of 1.5%. The total distance between railway connections is 6½ miles, and large yards will be provided on each river bank for the transfer of freight.

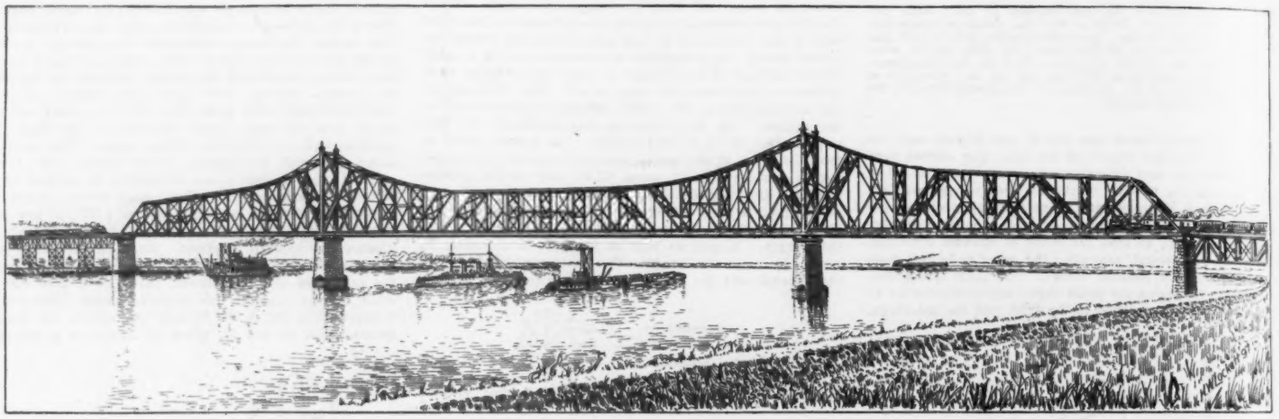
The special engineering features in the adopted design, here presented, are the great length of clear span, 1,000 ft., and the character of the foundation material. The site of the bridge is made up entirely of materials deposited by the Mississippi River, and borings to the depth of over 1,000 ft., made in the City of New Orleans, show only loam, sand, and some shallow strata of clay. Immediately at the bridge, borings 200 ft. deep show, at a depth of 50 ft. below low water, nothing but clean sand, growing coarser as the depth increases.

As designed, the bridge has a total length of 2,280 ft., measured from the centers of the shore piers. The center span is 1,066 ft. 8 ins. long, between centers of river piers, and this length is made up of a suspended span of 440 ft. and two cantilever arms of 313 ft. 4 ins. each. The anchorage spans are 606 ft. 8 ins. long each. The trusses are vertical, parallel and pin-connected, 40 ft. apart on centers and ranging in depth, between centers of chords, from 72 ft. at the shore ends, to 160 ft. over the river piers. Stiff members are used whenever feasible, in the bottom chords throughout, with stiff diagonals, instead of bars and counters, and stiff hangers at secondary panel points. The trusses are braced with heavy rigid horizontal and vertical transverse bracing.

The river piers are rectangular in shape, with projecting end starlings extending from the base to high water. These piers measure 30 × 97 ft. over all, at the base, and 18 × 54 ft. at the top coping; they are 128 ft. high and each pier contains 6,600 cu. yds. of masonry. The piers are founded upon timber caissons, measuring 60 ft. 8 ins. × 126 ft. 8 ins. at the base and 140 ft. high. These caissons are provided with open wells for dredging and closed pockets for concrete ballast; they will be sunk by dredging to a depth 70 ft. below the river bed. The corners of the caisson rectangle are cut off so that the square front opposed to the force of the current is reduced to 14 ft. The piers stand in about 100 ft. of water, and each caisson will contain about 4,500,000 ft. B. M. of timber and 13,300 cu. yds. of concrete. Heavy steel shoes will protect the lower edges of the caisson and these will be depended upon to cut through any timber obstruction encountered in sinking. The total fatigue weight on the foundation will exceed but slightly 6,000 lbs. per sq. ft. Brush mattresses, covered with rip-rap and extending 150 ft. from the ends of the piers and 100 ft. from the sides, will protect the piers from river scour.

The shore piers will rest on pneumatic caissons and these latter will be sunk 100 ft. below low-water. The piers will measure 22 × 62 ft. at the base and 10 × 50 ft. under the coping, and they will be 116 ft. high and contain about 2,850 cu. yds. of masonry. The caissons will be 31 × 61 ft. and 80 ft. high, and contain 750,000 ft. B. M. of timber and 7,200 cu. yds. of concrete. All of the piers will be built with a granite facing and concrete backing. The total height of the river piers is 450 ft., measured from the cutting-edge of the caisson to the top of the ornament on the vertical truss post.

Each approach will be made up of one pin-connected span of 150 ft., ten similar spans of [illegible] ft., and 26 60-ft. plate-girder spans. The total length of the metal structure will be 10,634 ft., or a little over two miles. The approach spans will rest upon steel towers, 30 ft. high, supported upon circular brick piers, with granite caps, concrete base and pile foundations. The remaining approach, 1,400 ft. on each side, consists of timber trestle and earth embankment. Mr. E. L. Corthell, M. Am. Soc. C. E., is the Chief Engineer of the Southern Bridge & Railway Company, and we are indebted to him for the above details.



PROPOSED BRIDGE WITH 1,000 FT. CHANNEL SPAN OVER THE MISSISSIPPI RIVER AT NEW ORLEANS.
E. L. Corthell, M. Am. Soc. C. E., Chief Engineer.

A CARNEGIE ARMOR PLATE, tapering in thickness from 16½ ins. at top to 9½ ins. at bottom, was tested at Indian Head on March 18. It represented 600 tons of armor intended for the battleships "Kearsarge" and "Kentucky." Two 10-in. shells were used in the test; the first weighed 500 lbs., and was delivered with a velocity of 1,380 ft. sec. It struck the plate where it was 12.1 ins. thick, penetrated 3 ins. and then broke up. The second shell had a velocity of 1,850 ft. sec. and struck 13.2 ins. of metal. This shell penetrated 7 ins. and then broke up. The metal around the point of impact was slightly dished, but otherwise the plate showed no signs of damage.

THE PAGE HIGH BUILDING BILL, passed by the New York State Senate on March 26, provides that the height of buildings shall be governed by the width of streets. The extreme legal height of a proposed building would be the perpendicular of a triangle formed by the intersection of this perpendicular by an imaginary line, starting from a point on the opposite side of the streeet 30 ft. above the curb-line, inclined at a slope of 2 on 1 towards the building; that is, on an 80-ft. street, the limiting height would be 190 ft. But for a 30-ft. street, like Nassau St., New York, the maximum allowable height would be only 90 ft. For the latter reason the bill is much opposed by real estate men, as they claim that the effect of the bill would be to enhance values on broad streeets and much decrease those on narrow downtown streets, regardless of business location and convenience to business centers.

THE U. S. GUNBOAT "WILMINGTON," built by the Newport News Shipbuilding Co., and especially designed for river service, made its official speed trial, on Mar. 27, in Long Island Sound. The contract speed was 13 knots per hour; this was greatly exceeded, and it is expected that her actual average speed will figure from 15 to 15¼ knots, over the 27-knot course. The "Wilmington" is 250 ft. 8¾ ins. long on the water line, with a beam of 40 ft. and a depth of 25 ft. 2 ins. With a displacement of 1,391 tons, she has a draft of 9 ft. She has a large military mast, with two military tops. She is propelled by triple expansion twin-screw engines of 1,600 I. HP., and has a fuel capacity of 280 tons. Her battery includes eight 4-in. rapid-fire guns and four 6-pdr. and four 1-pdr. rapid-fire guns and two Gatling guns, and the crew will be composed of 10 officers and 160 men. The "Wilmington" was contracted for, on Jan. 29, 1894, at $280,000 for hull and machinery.

THE FLORIDA GOOD ROADS ASSOCIATION was organized at Jacksonville, Fla., on March 23. Delegates were present from all over the state, and action by the legislature in favor of good roads and wide wagon tires will be urged by it.